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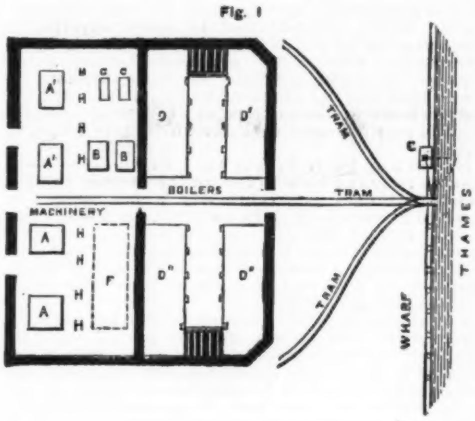
THE DEPTFORD CENTRAL STATION OF THE LONDON ELECTRIC SUPPLY CORPORATION.

THE system adopted is that of Mr. S. Z. De Ferranti, who is the engineer to the corporation, and under whom the Grosvenor Gallery Company, now incorporated with the London Electric Supply Corporation, has for a long time successfully supplied about 33,000 lamps from the Grosvenor station. For these particulars and illustrations we are indebted to the *Engineer.*

Fig. 1



The present buildings at Deptford are designed to contain engines and boilers of 43,000 horse power, ground being reserved for 80,000 more when wanted. The main building covers an area of 210 ft. by 195 ft., which is divided into a splendid pair of engine and machine houses, each 195 ft. by 36 ft., covered by roofs designed by Mr. Max am Ende, the ridges being 100 ft. above the ground; and a pair of similar colossal boiler houses 195 ft. in length and 70 ft. in breadth. The preliminary arrangements are being made for 250,000 lamps, but an ultimate output is provided for in the contemplated arrangements of 2,000,000 lamps.

The annexed outline plan gives some idea of the relative areas of the parts of the building and position of the machinery. The rectangles, B and C, Fig. 1, represent the positions of what are called the small engines and dynamos, the erection of which is now almost completed. These engines are 1,500 horse power compound, of the Corliss vertical type, built by Messrs. Hick, Hargreaves & Co., and have cylinders 28 in. and 56 in. in diameter, and 4 ft. stroke, the working pressure in the boilers being 200 lb. per square inch.

The dynamos, which are Mr. Ferranti's alternating current machines, designed for an electromotive force of 10,000 volts and of 1,250 horse power, are very rapidly being put together. They will each be driven by forty 5 in. ropes direct from the great fly wheel which is seen between the engine standards. Some idea of the very fine character of the building may be gathered from the very small part which is seen in the view, which, it must be noted, is only that containing the engines, B B, and machines, C C, in the plan Fig. 1. The columns which divide the large engine house into two, and support the line of rails upon which the big cranes run, are marked H H in the plan. Each of these machines, C C, is intended to supply 25,000 lights. Each of the rectangles marked A and A' on the plan shows the position of combined engines and dynamos of 10,000 horse power each, which are to be made and placed as the demand arises; those marked A' will be placed first, and are now actually in the builders' hands. The space on the plan marked F is for condensers for the engines, and the spaces marked D D' and D'' are those to be occupied by the boilers, which will ultimately be erected in batteries two stories high. Only those of the lower story at D are at present completed, and those at D' are nearly so.

The columns of the buildings have been designed and arranged so that the framework carrying the boilers can be fitted to them so as to make building and fittings all parts of one whole, just as is the case with the building, columns, cranes, and machinery of the other parts of the station.

The unprecedentedly high electromotive force which is to be employed will, of course, be confined to the mains between the central station at Deptford and what are to be known as distributing stations. Here will be the transformers, which are also Mr. Ferranti's design. These transformers will convert the 10,000 volt current to a 2,400 volt current, and this will be supplied to the transformers in the buildings of the users of the light. This may be illustrated by the accompanying diagram, Fig. 3, in which the circle on the left hand represents the dynamo at the central station. The center line from it represents the sending conductor, and the two lines the return conductor, between the central and a distributing station.

The main conductor consists of two concentric copper tubes, the inner one being thickly coated with an insulating composition, and the outer one passed over and drawn down upon it until it is tight. The outer tube, the return, is $2\frac{5}{16}$ in. in outside diameter and $\frac{3}{32}$ in. in thickness, and the inner tube $1\frac{9}{16}$ in. in diameter and $\frac{3}{16}$ in. in thickness, the sectional area of the two tubes being about the same. The outer tube will not be generally covered. Even if it became necessary to insulate, no danger would result from contact with the return near the central station, as only the difference between the potential at that point and the earth current from a distant earth would be felt by any one touching the exterior return conductor, for the fall in voltage is only about 10 per mile. As far as danger is concerned there is, therefore, no need of fear. The insulation of

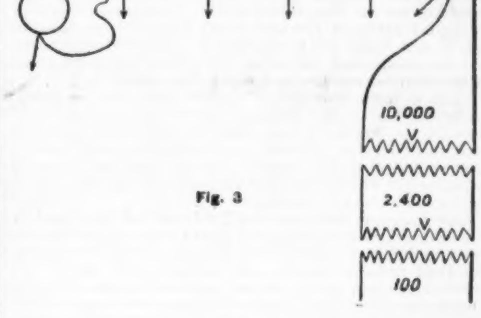
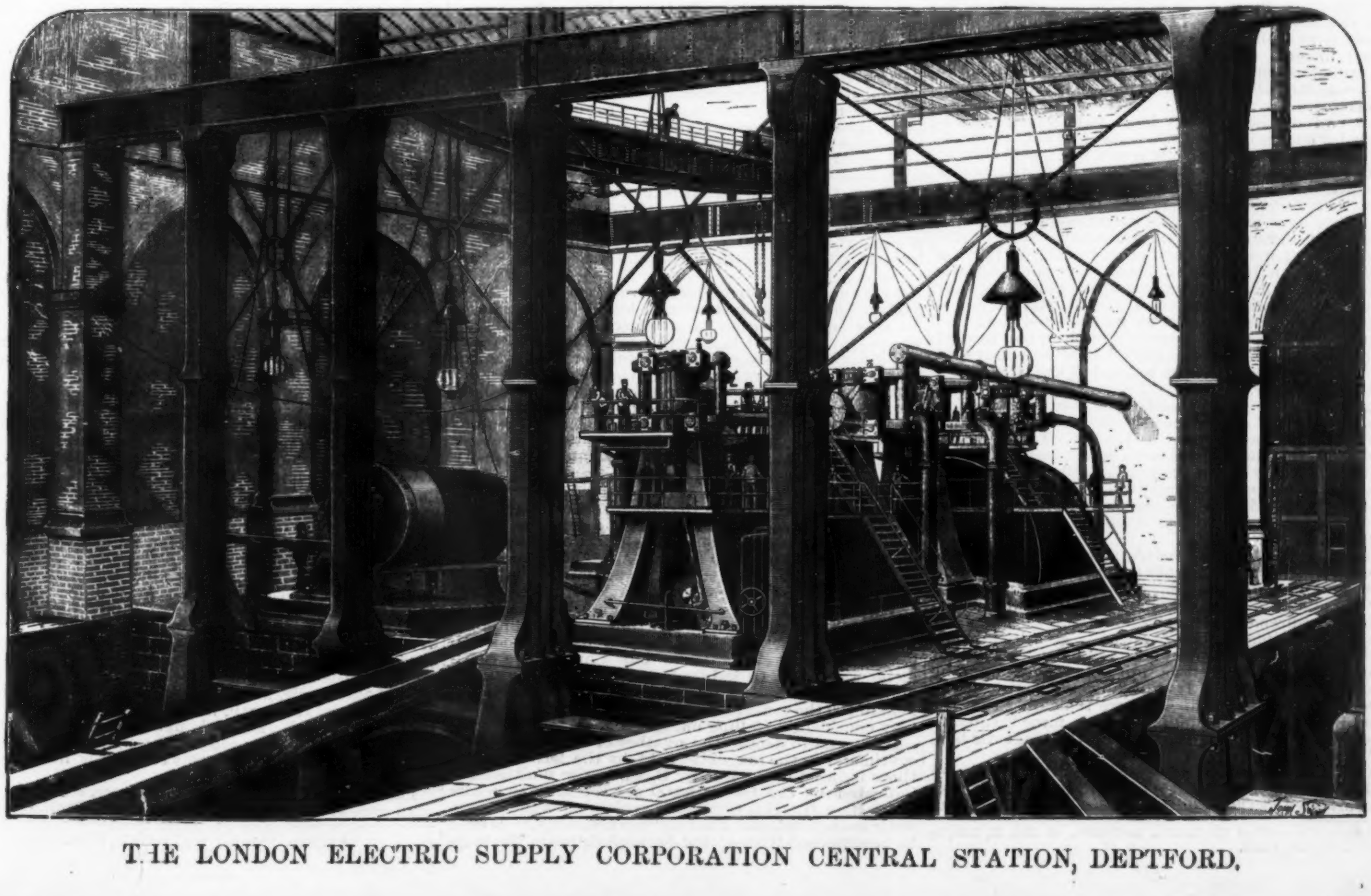


Fig. 3

the inner tube has been tested by a Wimshurst machine giving sparks over 10 in. in length, but it has not yet been found that the hundreds of thousands of volts so obtained have any effect on the insulation.

The diagram Fig. 3 refers only to one distributing station, at which the electromotive force falls from 10,000 to 2,400. From the latter are led wires which connect with the house transformers which reduce it to 100. The 10,000 volts thus only pass from the dynamos to the distributing stations, and cannot by any means affect anything beyond them. No difficulties which cannot be surmounted, and that without any noteworthy departure from the lines and details already laid down and fixed upon, are anticipated or are likely, although, of course, it is admitted that the jump from 2,400 volts, as used at the Grosvenor, to 10,000 volts is a big one, and one which is in the nature of an experiment. Mr. Ferranti is to be most sincerely congratulated on the design of the Deptford buildings and machinery and apparatus, and his enterprising and courageous departure from beaten tracks has before met with a success which we may expect to be repeated at Deptford.



THE LONDON ELECTRIC SUPPLY CORPORATION CENTRAL STATION, DEPTFORD.

SOME CURIOSITIES OF MAGNETISM.*

I PROPOSE to direct your attention this evening to a few points in the science of magnetism which lie a little out of the beaten track, and are interesting simply as scientific curiosities and for the light that they may tend to throw upon theory.

I shall refer to well known facts only so far as may be necessary for the purpose of linking together my curiosities into a more or less connected story; and since I wish to be perfectly intelligible to every one present, I ask the indulgence of those who are well acquainted with the subject if I am at times somewhat rudimentary.

The two most familiar pieces of apparatus, by means of which magnetic phenomena may be exhibited, are the magnet and the compass. An ordinary magnet is, as every one knows, a bar of steel, either straight or bent into the form of a horseshoe, which has the property of attracting and lifting small objects of iron or steel. A compass consists essentially of a thin, straight magnet—technically called a needle—having near its center a little cup, by means of which it is balanced horizontally upon an upright point.

The needle may easily be turned round in a horizontal plane; but when left undisturbed it always sets itself in such a position that its two ends point very nearly north and south. If we examine any magnet which has been bought at a shop, we shall probably see that one of its ends is marked with the letter N, or simply with a transverse line. This is the end which, if the magnet were suspended after the manner of a compass needle, would point toward the north.

The marked end is generally spoken of as the north pole of the magnet, the other or unmarked end being known as the south pole. The marked end of a magnet attracts the south end of a compass needle, and, if not held too near, repels the north end. So, also, the unmarked end attracts the north-pointing end of the compass needle, and repels the other.

These well known facts are expressed by saying that unlike poles attract, while like poles repel one another. A soft iron bar quite free from permanent magnetism attracts either end of the compass needle indifferently. If, however, a slight trace of magnetism be imparted to the bar, it will attract the two ends of the suspended needle with unequal forces.

This unequal attraction affords one of the simplest tests for magnetization; but it is by no means easy to apply such a test when we use a magnetic needle which, like that before you, is several inches in length. If, however, we use a very short magnetic needle, such as those contained in the small compasses that many of us carry on our watch chains, it is clear that we can hold the end of our test bar an inch or so from both poles at the same time, and if one pole is attracted more forcibly than the other, that pole will at once turn itself toward the bar and indicate that the bar is magnetized, and the direction of its polarity.

Experiments made with a pocket compass could not be shown to an audience, and I have therefore prepared a magnetic needle in such a manner that, although it is very small—less than ⅕ in. long—its indications will be easily visible to every one present.

The arrangement is very simple. Instead of being pivoted in the usual way, this little needle is suspended by a fiber of unspun silk, and it has attached to it a small circular mirror, which reflects a beam of light upon a large graduated scale attached to the wall. The movements of the spot of light upon the scale correspond with the movements of the little magnetic needle, and they not only indicate the direction in which the needle is deflected, but also provide us with the means of measuring its deflections.

This delicate apparatus, which we will call a "magnetometer," shows us that almost every piece of iron or steel possesses magnetic polarity. A knife, a pair of scissors, a door key, none of which have been intentionally magnetized, all cause the spot of light to be deflected either to the right or to the left, according to the end which is presented to the magnetometer. But I have here a short bar of soft iron which has been treated in such a manner as to destroy every trace of its permanent magnetism, and since its treatment it has been carefully guarded from accidental magnetic influences.

One end of the bar has been painted red; this is merely for convenience of reference, and is not intended to denote any magnetic difference whatever between the two ends. Holding this bar quite horizontally and in an east and west direction, I present one of its ends—say the red one—to the magnetometer.

If this is done carefully, no material deflection results. The spot of light remains almost steady. But if I disturb the east and west position of the bar by turning its black end a little to the south, the spot of light is immediately deflected toward the left, indicating that the bar has become magnetized, and that its red end is a north pole. Restoring it to its first position, the magnetism disappears. Turning the black end toward the north, we find that the spot of light now moves to the right, showing that the red end of the bar has become a *south* pole.

Again, if while preserving the east and west position we tilt the black end upward, we observe a violent deflection of the spot of light to the left. Lowering the black end, the spot moves with equal energy toward the right. These effects are produced by the magnetic force due to the magnetism of the earth itself. This is the force which directs the compass needle. It has, at any given place, a definite direction and a definite intensity.

The direction of the earth's magnetic force at any point in this room is, roughly speaking, from south to north, at an inclination of 67° to the horizon. Its intensity is equal to a little less than half a unit on the system of measurement generally adopted.

It is impossible on this occasion to go fully into the question of units, and it must be sufficient to say that in a field of unit intensity a unit pole is acted upon by a force of one dyne. It will, however, assist in the formation of definite ideas if we remember that the intensity of a unit field of magnetic force is equal to about twice the total intensity of the magnetic field due to the earth.

Now, the earth's total magnetic force, the direction of which is inclined at an angle of 67° to the horizon, may be considered as the resultant of two other forces, viz., a vertical force acting downward toward the center of the earth and a horizontal force acting from south to north. The intensity of the horizontal component is, again in round numbers, about one-fifth of a unit, while that of the vertical component is about two-fifths of a unit.

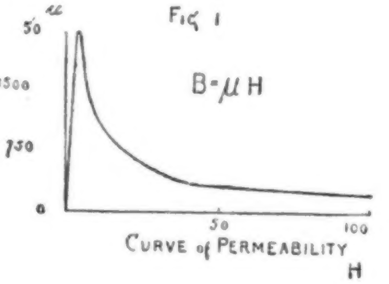
There is a convenient way, based upon a conception of Faraday's, of forming a mental representation of a field of magnetic force. The whole of the space in which the force acts is supposed to contain certain so-called lines of force, which we may picture to ourselves as ordinary physical lines. The direction in which the force acts is indicated naturally enough by the direction of the lines, while the intensity of the field is represented by the number of lines traversing a given space.

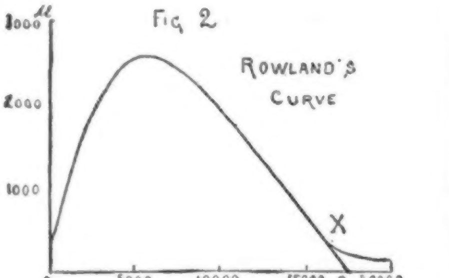
In a field of unit intensity these lines are supposed to be exactly one centimeter apart, so that if an imaginary flat surface were held transversely to the direction of the lines of force, then one line would pass through each square centimeter of the surface. In a weaker field the lines would be further apart; in a stronger one they would be packed more closely together. The earth's total field is, as I have said, of about half the unit intensity; there is, therefore, only one line to every two square centimeters of a transverse surface.

It must not, of course, be supposed that such lines have an actual existence distinct from the surrounding space, or that the magnetic force is in any way concentrated upon them. The conception is a purely artificial one, and, in spite of certain objections which may be urged against its adoption, it is found exceedingly convenient in imparting definiteness to one's ideas and in assisting calculations.

When a bar of iron is held in a magnetic field in such a manner that lines of force pass through its length, the bar is magnetized longitudinally, the end at which the lines enter becoming a south pole and that at which they leave a north pole. The effect of the earth's field is, of course, greatest when the bar is held at an angle of 67° to the horizon, its ends being at the same time directed toward the north and south.

The longitudinal effect disappears altogether when





the bar is horizontal, and its ends point east and west, for then no portion of the lines of force or of their vertical and horizontal components can traverse its length. But the mere fact of lines of force running through a thing does not necessarily develop sensible magnetic properties in it.

If we hold a rod of glass or of wood in a magnetic field, lines of force will pass through it; yet such a rod does not thereby acquire the power of attracting or repelling the pole of a compass needle. The fact is that iron, and in a less degree a few other metals, possess the remarkable property of multiplying the lines that would naturally fill the space occupied by them.

A long and thin iron rod placed in the earth's magnetic field will not merely be traversed by half a line of force for each square centimeter of its section, as a glass rod would be. The half line will be multiplied something like 400 times, raising the actual number of lines going through the rod to about 200 per square centimeter.

It is these lines, emerging from one end of the rod, reentering at the other end, that act upon magnetic poles in the neighborhood and cause the observed attractions and repulsions. By means of electric currents it is easy to produce magnetic fields having a far higher intensity than that of the earth. Here is a brass tube on which are wound several hundred convolutions of cotton-covered copper wire. When the current from a battery of Grove's cells is caused to circulate through the wire, a magnetic field is generated inside the tube, the intensity of which is about 300 units. A rod of iron placed inside the tube is traversed by perhaps as many as 18,000 lines per square centimeter.

Although this is a very large number, you will remark that it is smaller in proportion than was obtained when the magnetic field of the earth alone was employed. In that case a field of half a line to the centimeter was found to induce 200 lines in the iron, the multiplying power being 400. But with an external field of 300 the multiplying power is only about 60—a very considerable falling off.

It is usual to denote the number of lines per square centimeter in the magnetic field by the letter H, and those induced in the iron by B, while the multiplier is indicated by the Greek letter μ. We may therefore write $B=\mu H$. B is commonly spoken of as the "magnetic induction" and μ as the "permeability." It used to be supposed that, except for high values of the magnetizing force, the permeability, μ, was practically a constant for the same specimen of metal.

We have already seen that this is by no means the case, and how very far it is from being so is clearly shown by the diagram, Fig. 1, in which horizontal distances represent the magnetic force, H, and vertical ordinates the corresponding values of μ for an average specimen of soft wrought iron.

It will be remarked that, as the magnetizing force increases from the smallest values, the permeability at first rises with enormous rapidity, attaining in a field of 3 or 4 units a maximum value of more than 2,000.

Then it falls again, rapidly at first and afterward more slowly, until, with a field of 100 lines to the centimeter, the permeability is no more than 150. It is clear that within the limits of this diagram the lowest possible value has not been reached, and it is a matter of very great scientific interest to inquire what, if any, would be the ultimate permeability with an indefinitely strong field; or, in other words, to find an answer to the question, What is the greatest possible number of lines per centimeter that can be induced in a piece of iron, if indeed there be any limit at all?

To this problem Prof. Rowland, of the United States, applied himself fifteen years ago, and he believed that by a novel method of plotting his experimental results he had succeeded in solving it.

Instead of plotting values of μ against those of H simply, as is done in Fig. 1, he constructed some curves in which μ was plotted against the magnetic induction B, that is to say, against H multiplied by μ.

One of these curves is shown by the black line in Fig. 2. Like the former one, it begins with an ascent, reaches a maximum, and then falls with tolerable regularity. From data obtained by actual experiment, this curve was carried as far as the point marked X, before reaching which it had apparently become an almost perfectly straight line. Rowland therefore assumed that it would continue to be straight until it met the horizontal axis at a point which would give the greatest possible value of B for an infinite magnetic force.

He was thus led to believe that for iron the maximum of magnetic induction (*i. e.*, the greatest possible number of lines per centimeter which could pass through it) was about 17,000 or 18,000. Rowland's conclusion, or what has been regarded as its equivalent, is given in almost every text book of electricity and magnetism which has since been published, and it seems, in spite of its apparent anomaly, to have been generally accepted as correct.

Unfortunately, however, Rowland did not carry his experiments quite far enough. He left off with the comparatively weak magnetic field of 65 units, which induced in his iron the 16,500 lines per centimeter corresponding to the point X in the curve. If he had gone a little further he would have found that the curve, instead of continuing to fall, as he assumed, in a straight line to the point C, would bend aside in the manner shown by the dotted line in the diagram, ultimately becoming almost parallel to the horizontal axis.

This dotted line represents the results of some experiments in which the magnetic field was carried up to 585 units.* The corresponding magnetic induction was found to be about 20,000, exceeding by 2,000 the number which Rowland thought would be the greatest possible with a magnetic field of infinite intensity, and even then there were no indications that any limit was being approached.

In some recent researches by Prof. Ewing, an account of which was communicated to the Royal Society last November, these values have been enormously exceeded. Prof. Ewing succeeded in producing a magnetic field of no less than 24,000, and a piece of wrought iron in this field was found to be traversed by 45,300 lines per centimeter of section.

From the general character of his results, Ewing concludes that there is no limit whatever to the degree to which magnetic induction may be raised, and there can be no doubt that he is right. But it appears from other experiments described in the same paper that, after all, Rowland was not entirely wrong.

In a modified form, and subject to a little revision of the figures, his proposition turns out to be substantially correct. For while it is no doubt true that the number of magnetic lines which can conceivably be made to run through a piece of iron is infinite, we learn from Ewing's experiments that the number of new lines in excess of those contained in the magnetic field before the iron was placed there has a very definite limit.

This limit for the piece of wrought iron which he used appears to have been about 21,000, and it was practically reached with an external field of 2,000. For this sample of iron we may therefore say that in fields of 2,000 and upward $B=H+21,000$. In a field of 2,000 the induction would be 23,000; in a field of a million it would be a million and 21,000; but in either case the number of lines due solely to the presence of the iron would equally be 21,000. This important result may be expressed by saying that magnetic saturation is practically reached in a field of 2,000 units.

I have said that a unit line of force urges a unit north pole in a definite direction with a force of one dyne. A unit south pole would be urged with the same force in exactly the opposite direction. Now, every magnetized bar or needle has north and south poles of equal strength. When, therefore, such a bar is placed in a uniform field, its two ends are acted upon by equal and opposite forces. Thus the bar has no tendency to move bodily through space; it will merely set itself, if free to do so, with its length parallel to the direction of the magnetic force.

This fact is frequently illustrated by floating a cork with a magnetized needle attached to it in a basin of water. The needle, after a few oscillations, comes to rest in a north and south position; but it exhibits no tendency to move as a whole, either toward the north side or the south side of the basin. For the horizontal component of the earth's force is sensibly identical at both ends of the needle, and while at one end the needle is pulled toward the north, at the other end it is equally pulled southward. But although the earth's force may be regarded as quite uniform throughout a comparatively small space, such as this room, it is not so over the whole surface of the earth.

The horizontal force is, for instance, about 10 per cent. greater in the Isle of Wight than in Scotland, and

* Lecture delivered at the London Institution, on Feb. 11, 1889, by Shelford Bidwell, F.R.S.

* Bidwell, *Proc.* Roy. Soc., Vol. XL., p. 486.

if we could make a great bar magnet with its south pole at Ryde and its north pole at Edinburgh, and support it so that it could move freely in the direction of its length, the bar would at once start off in a southward direction, and, after traveling slowly across France and Spain, would finally come to rest with its middle point somewhere near the Gulf of Guinea, on the west coast of Africa, when its poles would find themselves in fields of equal intensity.

We can easily show a similar effect on a smaller scale. We set up the hollow coil of wire in an upright position upon a tripod, and arrange the connections in such a manner that when the battery current is flowing the lines of force pass through the interior of the coil in an upward direction. Inside the coil these lines are closely packed together and nearly parallel; beyond the two ends they spread out in all directions, like the branches of a tree. Below the coil we have a steel bar magnet, the north end of which enters the coil to the extent of an inch or two, while its south end rests upon a block of wood.

When we connect the battery by pressing a key, the magnet is at once lifted up bodily and drawn inside the coil in opposition to the force of gravity. Breaking the current, the bar falls back upon the block, the sound of its impact being audible throughout the room.

The reason is, of course, clear. As soon as the current is started, the magnet finds itself in a field of force, in virtue of which its north end is urged upward and its south end downward. But the field is not uniform, it is stronger inside the coil than outside. The force on the north end of the magnet, therefore, predominates over the opposing force on the south end, and the bar moves upward until (neglecting gravity) its two ends are in fields of equal intensity.

Instead of using a magnet, the experiment may be performed equally well or even better with a rod of common iron, for the lines of force in passing through the rod will convert it into a powerful temporary magnet with its north pole uppermost. The magnetism of the bar of iron when in a strong magnetic field may be demonstrated in the usual way by showing its power to attract any small iron objects, such as these nails.

It will be observed that not only does the iron rod attract the nails, but that the nails themselves have acquired the power of attracting each other, and hang in strings of considerable length. This is because the magnetic lines emerging from the end of the bar pass through the nails and convert them also into temporary magnets.

The moment that the current is broken the magnetic force vanishes; the iron loses its attractive power, and the nails fall to the table. We have here an example of what is known as an electro magnet, a convenient arrangement, by means of which a powerful attractive force can be instantly evoked and as instantly annihilated.

The little horseshoe-shaped piece of iron, not three inches long, which I hold in my hand, will, when an electric current is passing through the wire which is wrapped around it, easily lift a weight of 7 lb. Without the magnetic force which the current supplies, it is incompetent to pick up a single nail from this heap. Here I have a larger electro magnet which, with sufficient current, would probably support two or three hundredweights. Still larger ones have been made which can lift several tons.

The questions have often been discussed, what are the conditions affecting the lifting power of an electro magnet? and what is the greatest lifting power attainable? One point of fundamental importance was settled experimentally by Joule many years ago.

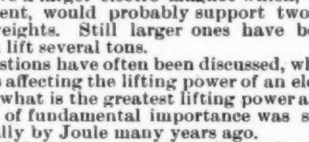
He found that the power of a uniform electro magnet varies directly as the sectional area of the iron core, so that, for example, a magnet with a section of two square inches would, other things being equal, carry twice the weight that could be supported by one with a section of only one square inch.

The same eminent philosopher carefully studied the effect of varying the strength of the current passing through the surrounding coil, and ascertained that while, up to a certain point, increase of current was accompanied by marked increase of lifting power, yet, when the current exceeded a more or less definite limit, further increase of it produced comparatively little effect.

Reasoning upon his experiments, he came to the conclusion, in which long afterward Rowland concurred, that no current, however great, "could give an attraction equal to 200 lb. per square inch." Recent researches have shown that this statement, though it has been very generally accepted, is not quite true. In some experiments made in 1886 with a semicircular electro magnet and a semicircular armature of soft iron, a weight of more than 200 lb. per square inch was easily carried, though the current employed was very far indeed from being infinite. It was, in fact, about five amperes, and the number of ampere turns per centimeter about 400.*

This question is indeed very closely connected with the one which we have already discussed with regard

Fig 3



DEMAGNETIZATION BY REVERSALS.

to magnetic induction. If there is no limit to the number of magnetic lines which can be induced in an iron bar, then, theoretically, there can be no limit to the lifting power which an electro magnet may be made to exert. Practically, however, a limit is imposed by the fact that we cannot command an unlimited current of electricity, nor would wires of any known material convey it, even if we could.

With sufficient current this little 3 in. magnet might, no doubt, be made to lift a weight of 20 tons; but any attempt to pass such a current would result in the immediate fusion, or even vaporization, of the wire by the intense heat that would be generated. The lifting power of an electro magnetic with an iron armature is proportional to the square of the total number of lines which run through the iron, a total made up partly of the lines due to the current in the coil (which would exist if no iron at all were present) and partly of the additional lines due to the superior permeability of the iron.

The effect may, therefore, be considered as resulting from the joint action of the iron core and of the surrounding coil. That portion of the attractive force which proceeds from the coil only is, with currents of ordinary strength, comparatively small. But we have to remember that it goes on increasing indefinitely as the current increases, while the portion due to the permeability of the iron attains, as we have seen, a limit. With very strong currents, the part played by the iron core would become relatively insignificant.

Fig 4

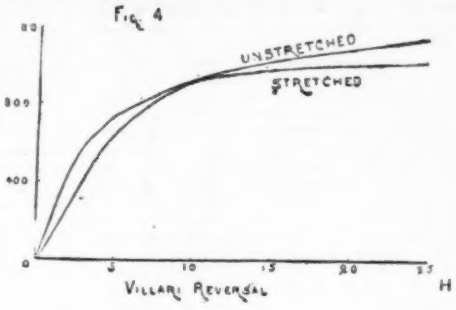


Fig 6

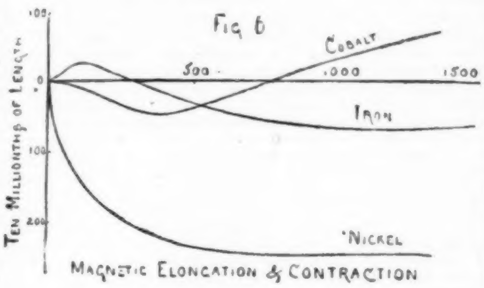
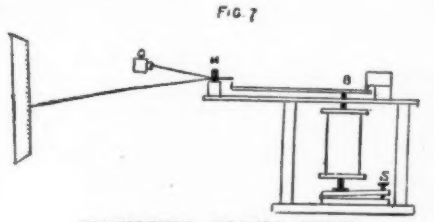


FIG. 7



MAGNETIC ELONGATION.

Thus, if it were actually possible to supply the 3 in. magnet with sufficient current to enable it to lift 20 tons, the effect would be almost wholly due to the coil, the iron itself supporting only a few pounds in virtue of its magnetization. Ewing's experiments enable us to determine the greatest weight that a magnetized iron bar could support by itself without any assistance from a surrounding coil. I find it to be about 260 lb. per square inch of section.

A rod of iron which has been magnetized by the action of a magnetic field is generally found to retain some of its magnetism when withdrawn from the field. This "residual magnetism," as it is called, is held much more tenaciously by hard steel or iron than by metals which have been softened by careful annealing. The reversed magnetic force which, while it is acting, is just sufficient to reduce the residual induction to nothing, has been called by Dr. Hopkinson the "coercive force." That force which not merely reduces the induction to zero while applied, but just suffices to destroy the residual magnetism permanently, he calls the "demagnetizing force."

In two specimens, the one of soft iron and the other of hard steel, which Hopkinson submitted to a magnetizing force of 240, the residual induction was found to be about 7.200 and 8,700 respectively; but whereas the coercive force of the iron was only two or three units, that of the hard steel was more than 19. A sample of steel containing about 2½ per cent of tungsten had a residual induction of 6,800, and required for its permanent demagnetization a reversed magnetic force of no less than 70. Such steel is of great value for the commercial manufacture of permanent magnets.

Vibration or jarring has a remarkable effect in removing the residual magnetism of soft iron. It also greatly assists the magnetizing action of a small force. I have here a soft iron bar painted red at one end. Holding the red end uppermost, I tap it gently with a wooden mallet; and now, reversing its position so that the red end is downward, I apply this end to the magnetometer. The movement of the spot of light at once indicates that the red end is a south pole.

The magnetization of the iron while under the influence of the earth's vertical force was facilitated by the tapping; some of the magnetism thus acquired was permanently retained, and hence the polarity now observed. But if, while thus holding the bar with the red end downward, I again tap it with the mallet, the spot of light immediately flies to the opposite end of the scale, indicating that the tapping has not merely depolarized the bar, but has enabled the earth's force to actually reverse its polarity. The red end, which was south, has now become north.

In experimental work it is frequently desirable to demagnetize samples of iron or steel which have been exposed to the action of strong fields. It would be easy to do this, at least approximately, if we knew what demagnetizing force would be just sufficient to destroy the permanent magnetism, and if we had the means of applying such force conveniently. This, however, is very rarely the case. But the desired object may be attained in another way.

The magnetized bar is subjected to a series of magnetizing forces which alternate in direction and gradually decrease in intensity until they become exceedingly small. Under each successive application of the force, the magnetism of the bar is reversed, and at the same time diminished, finally disappearing altogether. I have arranged an apparatus by means of which this operation of demagnetization by reversals can be performed very conveniently.

Its nature is indicated in Fig. 3. A B represents a German silver wire wound in a close spiral upon a wooden cylinder, along which a contact spring, C, is capable of sliding. The two ends of the wire are connected through a current reverser, D, with a battery, E. One end, B, of the wire and the spring, C, are also connected with the hollow coil, S, inside which is placed the bar to be demagnetized. The resistance of the whole of the German silver wire being many times greater than that of the coil, S, it follows that when the sliding spring is at the end, A, of the cylinder, the proportion of the current which passes through the coil is much greater than that passing through the German silver wire. As C moves from A to B, the current through the coil, S, becomes gradually less and less, and when B is reached there is practically no current in the coil at all.

While the current is being thus diminished in strength, its direction is reversed many times by means of the commutator, D, and in this manner there is produced a succession of alternating magnetic forces of diminishing strength, which have the effect of demagnetizing the iron bar inside the coil. In the instrument before you the slide and the commutator are actuated simultaneously by the simple operation of turning a handle.

Here is a bar which, when applied to one of the poles of the magnetic needle, causes repulsion. It is, therefore, magnetized. We place it in the instrument, and after a few turns of the handle, we once more test the bar. Finding that it now attracts both poles of the needle indifferently, we know that it has been freed from permanent magnetism.

We have seen that the permeability of an iron rod (and, therefore, its magnetic susceptibility) depends upon the intensity of the field in which it is placed. But even in the same field its value is subject to some variation, for it also depends, to some extent, upon the physical condition of the iron, and is affected by such causes as changes of temperature or mechanical stress.

If, for instance, we hang an iron wire vertically in a not very strong field, and stretch it a little by attaching a weight to its lower end, we shall find that the stretching causes a temporary increase in the permeability of the wire, and, consequently, in the intensity of its magnetization; the wire will act more powerfully upon a magnetometer, and produce a greater deflection in the stretched than in the unstretched condition. But if the experiment be repeated in a strong field, the effect will be reversed. The same load which before increased the magnetization of the wire will now be found to diminish it. In a field of a certain medium strength, which can be determined by trial, the stretching will have no effect at all upon the magnetization.

This value of the field is called, after the first discoverer of the phenomenon, the "Villari critical point" for a certain load. The diagram, Fig. 4, shows the results of some experiments upon an iron wire about three-quarters of a millimeter in diameter, in both the unstretched and the stretched conditions, the load employed being a weight of 7 lb.

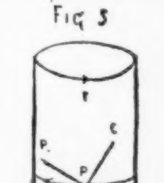
In this diagram the horizontal distances are proportional to the magnetizing field and the vertical distances to the corresponding magnetization. The critical point, where the two curves cross each other, occurs when the intensity of the field is about 11 lines of force to the centimeter.

There can be little doubt, though I do not know of any experiments that have been made on this point, that the effects of compression would be of the opposite character to those produced by extension. The action of strain upon susceptibility no doubt explains a very curious effect, first noticed, I believe, by Prof. Wiedemann, which occurs when a circularly magnetized iron wire is twisted.

It may be well to explain what is meant by circular magnetization. Suppose that we magnetize a strip of very thin iron or steel and bend it into the form of a ring like an ordinary napkin ring, making the joint between the ends so perfect that there is no break whatever in the continuity and uniformity of the iron.

Such a ring will exhibit no external indication of magnetism, for the lines of force which proceed from the north pole will at once enter the south pole without passing through the air at all. By properly joining a number of such rings together we might form a circularly magnetized tube, and if we filled up this tube with a series of similarly prepared tubes of gradually decreasing diameter, fitting perfectly one within the other, we should build up a circularly magnetized solid rod.

Fig 5



WIEDEMANN'S TORSIONS

A rod so constructed would, like the elementary rings composing it, yield no sign of magnetization to ordinary tests, for no lines of force would issue from it

* Bidwell, *Proc.* Roy. Soc., Vol. XL., p. 487.

into the surrounding space. Nevertheless, it would be magnetized. An iron rod or wire may be circularly magnetized by the simple operation of passing an electric current through it.

Here is a piece of thick iron wire which has been so treated. Bringing one end of the wire near the magnetometer, we see that no material deflection is produced. But if, while holding the end of the wire which is nearest to the magnetometer as steadily as possible, I give a slight clockwise twist to the other end, the spot of light is deflected violently toward the right, indicating that the fixed end of the wire has become a strong south pole. If we reverse the twist, the polarity is at once reversed, and the spot of light flies to the opposite end of the scale. We may repeat this operation a great many times, giving the wire either polarity at will by the application of a suitable twist at the free end.

Prof. Chrystal has given an explanation of this phenomenon which appears to be quite satisfactory. Fig. 5 is intended to represent short length of a wire which has been circularly magnetized by a current passing from above downward. The magnetic force of any point, P, in the wire is in the horizontal direction, P B. Suppose the wire to be fixed at the bottom and to be twisted at the upper end in the direction indicated by the arrow head, T (*i. e.*, in a counter clockwise direction as seen from above), then the metal is stretched in some such direction as P E, and compressed in another direction, P R. P E and P R therefore become axes of greatest and least susceptibility, and the resultant magnetization will take the direction, P B', which has a vertical component downward in the direction, P A. The lower end of the wire should, therefore, exhibit north polarity, as the experiment shows that it does. The effect caused by stress upon the susceptibility of the magnetic metal nickel is opposite to that produced in iron. Stretching diminishes its susceptibility, compression increases it.

Hence, if we perform the twisting experiments with a wire of nickel instead of iron, the resulting polarities should in each case be the contrary of those which we just now observed. This also agrees with the experiment. We now pass to the consideration of what appears to be a class of converse phenomena. As the magnetic qualities of a rod of iron or other magnetic metal are affected by temporary strain or slight alteration of its form, so it has been found that the form of such a rod may be slightly altered by magnetizing it. About the year 1840, Joule ascertained, by the aid of a delicate piece of apparatus, that a bar of iron became a little longer when it was magnetized, resuming its original length on the disappearance of the magnetism. The experiment is a well-known one, and is often referred to as tending to throw light on the real nature of magnetic phenomena. But the simple statement that an iron rod is lengthened by magnetization does not contain the whole truth.

Joule found that when he gradually raised the magnetizing force from a small initial value, his iron bars at first increased in length somewhat quickly and afterward more and more slowly, until when the magnetizing force had reached about 100 units they appeared to have attained a limit, and ceased altogether to expand. At this point, therefore, Joule stopped his experiments, and for 40 years or more it seems that no one else ever carried them any further. In the year 1885 an accidental observation led me to believe that there was still something to be learned about the matter, and I accordingly proceeded to repeat the experiment with far stronger magnetizing forces than had previously been employed. The latest results are clearly shown in the diagram Fig. 6, in which the horizontal ordinates represent the magnetizing force in C. G. S. units, and the vertical ordinates the elongations in ten-millionths of the length of the rod.

Looking at the curve marked "iron," we see that as the magnetizing force rises from zero up to 125 units, the rod gradually becomes longer. But when the magnetizing force is raised beyond this value, the rod, instead of retaining its maximum extension, begins to contract again, resuming its original length with a force of about 275. Still further increasing the force, the iron is found to become actually *shorter* than it was in the unmagnetized condition; and it continues to contract until the force has attained the value of about 1,000, beyond which point its length becomes sensibly constant. The same diagram gives the results of experiments made with the two other magnetic metals, cobalt and nickel.

Cobalt, it will be seen, behaves oppositely to iron; it begins by contracting, and after attaining a minimum length, becomes longer again. Nickel also is found to contract, but, unlike cobalt, it never passes a minimum, its length remaining unchanged when the magnetizing force exceeds the value of about 800. The contraction of nickel under magnetization had been previously observed by Prof. Barrett. It must be remembered that the absolute magnitude of these elongations and retractions is exceedingly small. Thus the greatest elongation of the iron rod used in these experiments was barely 6 millionths of an inch. The measuring apparatus is, therefore, necessarily one of great delicacy. That which I have constructed, and which is now before you, will measure small changes of length, to one 25-millionth of an inch. Imagine an inch to be divided into so many equal parts that to count them at the rate of 100 a minute day and night, without ever resting, would require six months' continuous work; then this instrument is capable of measuring one of such parts.

The nature of the apparatus is indicated in Fig. 7. The iron rod to be examined is placed in an upright position inside the magnetizing coil.* Its upper end acts at B upon a long lever which turns upon a knife edge very near to B; the other end of the lever tilts a small mirror, M, which also turns upon knife edges, or rather needle points. By means of a lime light lantern the image of a horizontal wire is, after reflection from the mirror, projected upon a distant vertical scale. A very slight deflection of the mirror causes a considerable movement of the image, and from the extent of this movement the change in the length of the wire can be easily calculated. In a rude kind of way I can show you the instrument in operation. The image of the wire is seen as a black line across the scale which is hanging upon the wall.

* For further details of the arrangement see *Proc.* Roy. Soc., No. 242, 1886, p. 110, and *Phil. Trans.* vol. clxxix. (1888), A, page 205. The instrument used at the lecture was made after the latter paper had been communicated, and was exhibited at the Royal Society soiree in May, 1888.

When a current of electricity of sufficient strength to produce a field of about 100 is passed through the coil, the image of the wire at once moves downward, showing that the length of the iron rod has become greater. A current five or six times as strong as the last is now turned on. Immediately the black image moves in the upward direction, indicating a diminution in the length of the iron. It has lately been shown, mathematically, by Prof. J. J. Thomson, of Cambridge, that this remarkable behavior of an iron rod, in elongating with a moderate magnetic force and contracting with a strong one, is a necessary consequence of the phenomenon which has already been spoken of as the "Villari reversal." This being so, we may venture to make a prediction with regard to cobalt and nickel.

We can foresee with tolerable certainty that, if the experiment were made, a Villari reversal would be found to occur with cobalt, and that it would be of the opposite character to that in iron—*i. e.*, stretching would diminish the magnetization when the magnetic force was weak and increase it when the magnetic force was strong. I am not aware that such an effect has been yet observed. In nickel, on the other hand, there will be no Villari reversal at all. This latter statement has already been to some extent verified, since, although several attempts have been made (some quite recently by Prof. Ewing) to detect such reversal, none has been attended by success.

A few words in conclusion with regard to the effect of heat. Iron, when made red hot, loses its susceptibility, and practically becomes a non-magnetic metal. Nickel loses the greater part of its magnetic property at a much lower temperature, perhaps about 300° C. I have here a piece of apparatus in which this effect is rather neatly shown. A copper disk to which a thin projecting tongue of nickel is soldered hangs like the bob of a pendulum from a double thread. This bob is drawn out of its normal position by the action of a horizontally fixed bar magnet, which attracts and holds fast the nickel tongue. We place a spirit lamp beneath the tongue. In a few seconds the heat destroys the magnetic quality of the nickel, so that the magnet can no longer hold it. The bob accordingly falls back under the action of gravity, and performs an oscillation. In the course of its swing, however, the metal becomes cooler, and when it returns to the neighborhood of the magnet, the tongue is once more attracted. But again becoming heated by the flame, it is instantly liberated, and the process is repeated. By properly regulating the size of the flame, the bob may be kept swinging for a considerable time, like the pendulum of a clock, especially if the uniformity of the action is not affected by currents of air. This exhausts the list of curiosities which I have selected for review this evening. If they do not, for the most part, appeal very strongly to the commercial instincts of the so-called practical man, they are nevertheless of much scientific interest, and no molecular theory of magnetism will be complete which fails to give a full account of every one of them.

THE EIFFEL TOWER.

WE give herewith an engraving of this great work, for which we are indebted to *Industries*, and from *Engineering* we gather the following particulars:

The Eiffel Tower is the natural development of the class of work upon which its constructor has been occupied for so many years; it was the direct outcome of a series of investigations undertaken by M. Eiffel in 1885, with a view of ascertaining the extreme limits to which the metallic piers of viaducts could be pushed with safety, this special line of investigation having reference to a proposed bridge with piers 400 ft. in height and 140 ft. of base. The idea of the great tower followed, preliminary plans were prepared, and calculations made by two of M. Eiffel's principal engineers, MM. Nouguier and Koechlin, and by M. Sauvestre, architect. Naturally the leading principle followed was that adopted by M. Eiffel in all his lofty structures, namely, to give to the angles of the tower such a curve that it should be capable of resisting the transverse effects of wind pressures without necessitating the connection of the members forming these angles, by diagonal bracing. The Eiffel Tower, therefore, consists essentially of a pyramid composed of four great curved columns, independent of each other, and connected together only by belts of girders at the different stories, until the columns unite toward the top of the tower, where they are connected by ordinary bracing. Iron, and not steel, was used in the construction throughout.

There are four independent foundations, each standing at one angle of a square, about 330 feet on a side; the two piers nearest the Seine were known as numbers 1 and 4, those adjoining the Champ de Mars as 2 and 3. On the site of the two foundations 2 and 3, the bed of gravel was met with 23 ft. below the surface; the thickness at this point is about 18 ft. The conditions for obtaining a good foundation were therefore extremely favorable, and the piers were built upon a bed of cement concrete 7 ft. in thickness. The two piers nearest the Seine required different treatment. The bed of sand and gravel was only met with about 40 ft. below the surface, that is to say, about 16 ft. lower than the mean water level of the Seine, and it was overlaid by soft and permeable deposits. Excavations were pushed, by means of caissons and compressed air, to a depth of about 52 ft. below the surface, and it was found that, under the gravel, variable deposits of fine sand, formed of limestone and sandstone, had accumulated, having been left there by the water after the clay had been washed out in hollows by the stream. Owing to this there existed a good and incompressible bed about 10 feet thick under the western pier on the Grenelle side and nearly 20 ft. thick under the north pier on the Paris side. Apart, therefore, from the difficulties in sinking for the foundations, the conditions were very satisfactory. The mode of sinking adopted was that of compressed air, with iron caissons 49 ft. 2 in. long by 19 ft. 8 in. wide; four such caissons were required for each pier, and they were sunk to a depth of 40 ft. below the surface, or 16 ft. lower than the Seine mean water level.

The tower terminates at a height of 896 feet above the ground, with a platform about 53 feet square. The width of the column at this level is 33 feet, the gallery being carried by brackets which are sufficiently wide to afford a considerable area of platform. It is almost unnecessary to state that this space is securely protected by a railing and glass to prevent any voluntary or involuntary catastrophe. Above the platform rises the campanile, which is of the design shown; in the lower part of this is established a spacious and very completely fitted laboratory, closed to the public and intended for the prosecution of scientific research and observation. Four latticed arched girders rise diagonally from each corner of the lower part of the campanile and unite at a height of about 54 feet above the platform. By means of a spiral staircase yet another gallery is reached, about 19 feet in diameter, and surrounding the lantern which crowns the edifice and brings the height of the structure to 984 feet. Above this rises the great lightning conductor. Within the lantern, which is 22 feet high, will be placed a very powerful electric light, placed within a lantern of the first order, and projecting white, blue, and red beams. Reflectors will throw these beams over Paris, and will help to illuminate the Champ de Mars.

Provision is made for protecting the structure from the effect of lightning by means of cast iron pipes, 19 inches in diameter, and passing through the water-bearing strata below the level of the Seine for a distance of 60 feet. At one end these pipes are turned vertically, and are connected with the ironwork of the tower. There are eight pipes in all, two for each column.

The total weight of wrought and cast iron that has been used in this unique structure is 7,300 tons, not including the weight of the caissons employed in the foundations nor the machinery installed for working the elevators.

No doubt during the period that the exhibition is kept open the ample facilities thus provided for the public will not be found excessive, but it is scarcely reasonable to suppose that after all the buildings on the Champ de Mars have been swept away, and the vast column alone remains to suggest the glories of the departed centennial celebration, great numbers of visitors will go so far out of Paris as the Champ de Mars to enjoy a sensation which by that time will have ceased to be novel. It is to be hoped that, by the time the exhibition closes, the enterprising syndicate which has acquired the Eiffel Tower will find themselves repaid to a large extent. Otherwise there is reason to fear that their speculation may not turn out profitable, and that their twenty years' concession will scarcely suffice to make their speculation a satisfactory one.

But of course the tower has other uses than that of money making, some uses which are now apparent, and others which the existence of the structure will suggest as time goes on.

We may conclude this notice with a few miscellaneous particulars of this interesting work. The total weight of iron employed in the structure itself is 7,300 tons. The weight of rivets is 450 tons, and their total number 2,500,000. Of this quantity 800,000 were riveted up by hand on the tower itself, during the work of fixing together the finished pieces which had been completed at M. Eiffel's establishment at Levallois-Perret, and which were delivered on the Champ de Mars ready for erection. The number of pieces of iron of different forms is 12,000, and each of these required a special drawing; there were thus no less than 12,000 working drawings sent into the workshop, to say nothing of the innumerable sketches and plans prepared before the final details were decided upon. The total thrust upon the foundations is 565 tons, not including the effect of wind, and 875 tons under a maximum wind pressure. The tower is painted of a rich chocolate color, the tone of which is lightened from the base toward the summit. The painting, which was of itself a considerable work, is very effective, especially when lighted by the sun. But little decoration has been attempted; it would have been wasted labor and expense. The level of the first story is marked by a bold frieze, on the panels of which, around all four faces of the tower, are inscribed in gigantic letters of gold the names of the famous Frenchmen of the century who have most contributed to the advancement of science.

"It is as it were under their patronage that this monument is erected, and the constructor has desired to consecrate to them the place of honor, and upon it to write their names in letters of gold, as an evidence of public recognition, and as of homage paid to their efforts, without which such an enterprise could never have been attempted."

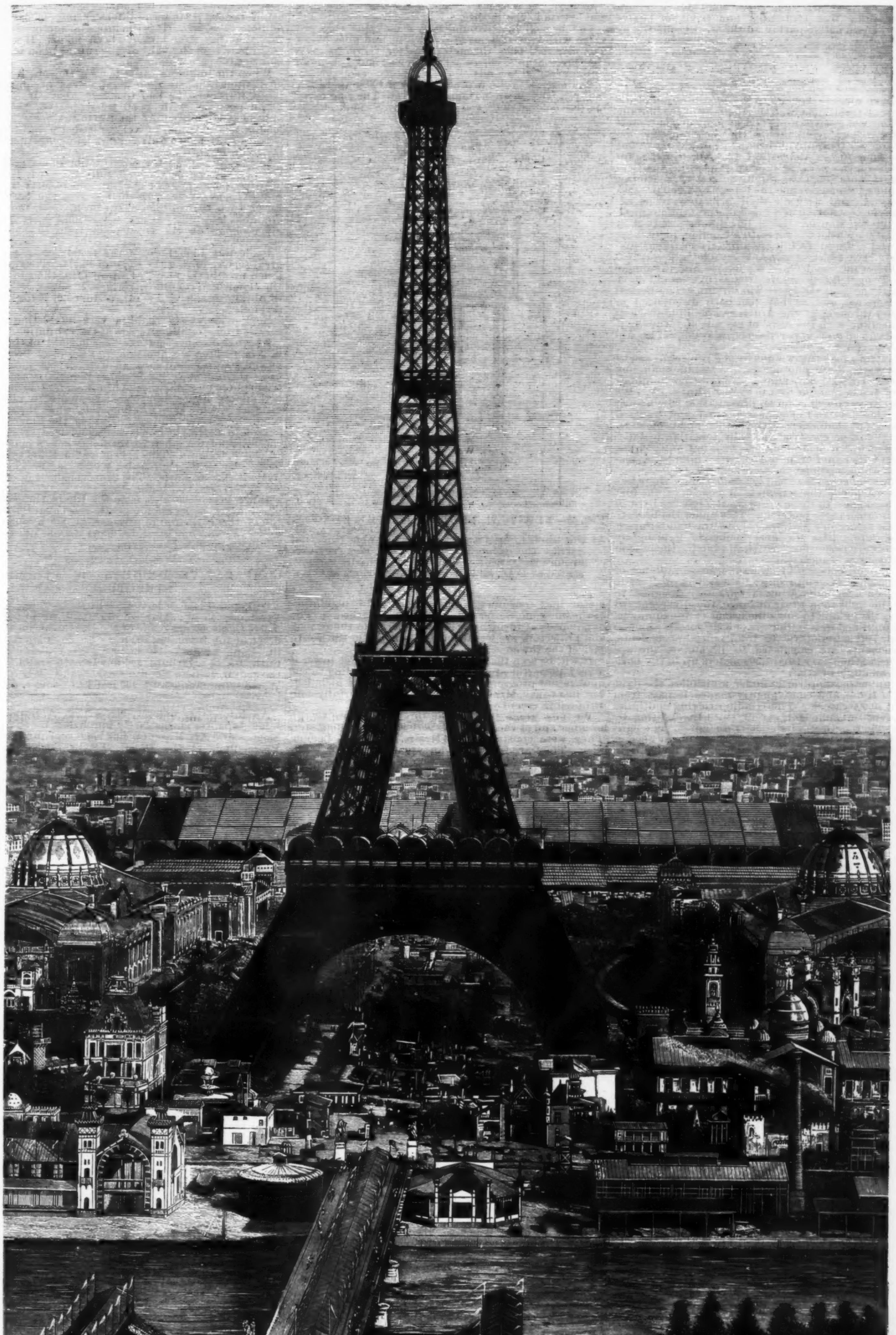
Above this frieze the four-sided arcade, covering the exterior gallery, is elaborately decorated, and considerable exception has been taken to this feature as marring the bold and graceful outline of the tower. A similar arcade encircles the tower at the level of the second story, and the same objection may be raised with regard to it, but with less force, because the great height makes the arcade look insignificant. The sloping arches and spandrel fillings which connect the columns of the tower on the four faces beneath the first story are singularly well adapted to the gigantic scale of the work.

Very careful observations were made from time to time as the erection of the tower advanced to check its verticality. These observations showed conclusively that the foundations had not yielded at all under their very moderate load, and that if any deviation from the vertical existed, it was so slight as to be scarcely appreciable with the most careful measurement. All the other calculations of M. Eiffel have been so complete and accurate, and his experience with high structures so exceptional, that his assurance may be taken with confidence that the oscillations of the tower at the summit under the most unfavorable conditions of wind pressure will not exceed 6 inches, while the periods of vibration will be relatively slow. Under ordinary conditions of weather the tower will remain absolutely rigid.

The success of the many problems attending the erection of the tower has been complete, and does M. Eiffel much honor.

The remarkable regularity with which this erection has been accomplished, and the fact that no correction of any kind was ever required, is an ample proof of the precision with which the innumerable parts that compose the structure were turned out from the ateliers of Levallois-Perret. This achievement also shows how well the arrangements for the erection were combined, all having come to pass as had been foreseen, without error, without accident, and without delay.

To obtain such a result, M. Eiffel has been admirably seconded by MM. Nouguier and Koechlin. M. Nouguier, who is chief engineer to the Eiffel firm, had the entire management of the erection of the famous bridge over the Douro (Portugal). He and his colleague, M. Koech-



THE EIFFEL TOWER (984 FEET HIGH) AT THE PARIS EXHIBITION.

lin, are well known for their entire competence in matters regarding iron structures, and have for twelve years taken an active part in all the works achieved by M. Eiffel.

THE BEACON AND PROJECTORS OF THE EIFFEL TOWER.

WE have already spoken of the inauguration of the Universal Exposition and of the splendor of the illumination that was gotten up in the evening of that same memorable day. Thanks to the inexhaustible resources of photography, it is now possible to give our readers some idea of the aspect that the Eiffel tower exhibited on the evening of May 6th, while the Bengal lights were burning on its successive platforms and while at the same time the beacon and the projectors were shining with all their brilliancy. The accompanying engraving is a facsimile of a photograph taken by Mr. Maurice Gavin, on Monday, May 6, at half past 9 o'clock at night with a Lumiere plate (blue mark) and a rapid rectilinear objective without diaphragm. The effect obtained is curious and very exact. The wind was driving the flames and the smoke of the Bengal lights before it, and one would have said that the iron structure was on fire. The Bengal lights were red, and as they had been distributed in profusion throughout the structure, the illumination, in connection with the rows of gas jets and the light of the beacon and upper projectors, produced an absolutely enchanting effect.

The intense rays thrown out by the projectors can be distinctly seen in the photograph. A luminous aureola appeared a little way above, around the luminous point of the beacon, as well as at the third story. We shall no longer dwell upon an illumination which must be considered merely as an exceptional and unusual spectacle, but shall describe the beacon and projectors. These apparatus constitute a really scientific installation, which Mr. Eiffel had carried out by Messrs. Sautter & Lemonnier, and the entire interesting features of which we hope to make understood.

At the very summit of the 300 meter tower there has been constructed the cupola of a beacon of the first order, analogous to those of our coasts, but the light of which is much more powerful. It is under the beacon, upon the laboratory platform, above the hall set apart for the public, that the experiments in lighting by projectors are performed. We shall examine the beacon and projectors in succession.

The beacon consists of two superposed systems of optical elements, comprising: (1) a system of dioptric glasses, or a cylinder (simple refractor) designed to throw the light to a great distance, the divergence of the rays being due to the dimensions of the luminous source obtained by a voltaic arc of 5,500 carcels; and (2) a system of catadioptric or total reflection elements. The elements are calculated to illuminate the approaches to the tower from 1,500 meters up to the horizon, at an angle of 11½°.

The upper or dioptric cylinder multiplies the light thirteen times, and consequently makes it pass from 5,500 to 70,000 carcels. The catadioptric ring multiplies it to a less, but sufficient, extent, since the lighting by this system is designed for shorter distances. The light thrown out by these superposed rings of cut glass is graduated according to the distance, and increases in measure as one recedes from the axis of the tower. The intensity of the flashes visible at Paris is 24,146 carcels at 1,503 meters from the tower; 64,474 carcels at a distance of 1,850 meters; 86,711 carcels at a distance of 2,194 meters; and 99,283 carcels at a distance of 2,500 meters. At 4,120 meters the cylinder begins to make its effects felt.

Its intensity is 69,398 carcels in the stationary light and 516,716 in the flashes.

The beacon in surrounded by a movable ring provided with two systems of red, white, and blue lenses. The rays that pass through the latter therefore have the three national colors. These lenses make one revolution every 90 seconds.

The electric light is produced by a 100 ampere current received in an automatic lamp. The ring carrying the colored lenses is actuated by a small electric

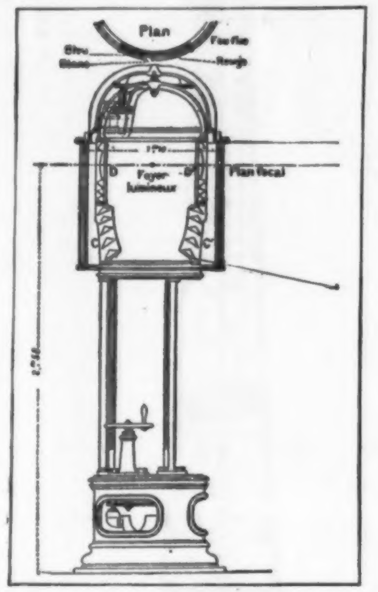


FIG. 2.—VERTICAL SECTION OF THE BEACON.

At the top is figured a plan of the movable ring that carries the colored lenses. This ring revolves around the beacon. The dioptric cylinder is represented at D D', and the catadioptric rings at C C'.

motor that consumes ½ an ampere. The regulation of the luminous center is done with great precision. The dynamos that furnish the electric energy to the beacon and projectors are located at the surface in the south pier of the tower.

It will be seen that the beacon of the Eiffel tower is a very powerful apparatus, arranged according to the most recent progress in industrial optics, to which, it is but just to say, Mr. Gaston Sautter has powerfully contributed in recent years.

We now come to the projectors. These are two in number and of the Mangin type, 0·9 meter in diameter. They were constructed by Messrs. Sautter & Lemonnier. They are formed of an aplanetic mirror. The light is furnished by an electric arc lamp placed very near the mirror and of the same intensity as that of the beacon. The carbons of this lamp are inclined at an angle of 45°. The projector, which is mounted upon a pedestal, is moved in all directions through the aid of two hand wheels.

As the ray projected is distributed over a small surface, it is found to be much more powerful than that of the beacon. Its mean intensity is from six to eight millions of carcels. It is the intensest luminous projection that has ever hitherto been made. It is well to recall here that the light of the sun at noon is equivalent to 6,000 carcel lamps.

When the luminous ray falls upon objects, it permits of distinguishing all their details, even at a great distance, if recourse be had to a telescope. It has been found possible, with good telescopes, to distinguish objects at 6¼ miles. At the top of the tower, the projectors are capable of very distinctly lighting the Orleans station, the July column, and consequently all the buildings of Paris.

One peculiarity of the construction of the projectors is that they can be inclined fully 45°. It is therefore possible to illuminate close-standing objects from top to bottom as far as to 275 meters from the base of the tower, such, for example, as the group of statues of the luminous fountain. It has been found possible to follow up boats on the Seine, pedestrians in the streets, etc.

Projectors like those of the Eiffel tower rendered great service during the siege of Paris. They are now much used in the navy. By projecting their rays upon the clouds and occultating them, it might be possible to obtain signals visible at a distance of 300 kilometers (180 miles).

Such experiments would be very interesting ones to carry out during the progress of the exhibition.

At what distance can the beacon light of the tower be seen? That is a question that has often been asked us and that we shall now answer. At 300 meters altitude, the luminous ray becomes tangent to the terrestrial sphere at a distance of 67 kilometers (40 miles). It is therefore impossible to see the luminous point at a distance of more than 67 kilometers, when the observer is at the level of the sea. But as the range of the beacon in a straight line is 203 kilometers (121 miles), it can be seen from much further off, when a person is in an elevated place. The beacon of the Eiffel tower has been seen at Bar-sur-Aube, which is 190 kilometers (114 miles) from Paris. The observer stood upon a hill 300 meters (984) feet high.

It has been seen also from the top of the cathedral of Chartres, at 75 kilometers (45 miles), and from the top of the cathedral of Orleans, at 115 kilometers (69 miles). From these great distances it looks like a simple luminous point.—*La Nature.*

FIG. 1.—THE EIFFEL TOWER ILLUMINATED ON THE EVENING OF THE INAUGURATION.

COMPARATIVE HEIGHTS OF CELEBRATED STRUCTURES.

OBELISK, Place de la Concorde, Paris, 27 m.; Column Vendome, 45 m.; Arch of Triumph, 49 m.; spire of Notre Dame, 66 m.; dome of the Pantheon, Paris, 83 m.; dome of the Invalides, 105 m.; Church of Milan, 109 m.; St. Paul, London, 110 m.; St. Peter's, Rome, 132 m.; Cathedral of Strasburg, 142 m.; Great Pyramid, 146 m.; Cathedral, Rouen, 150 m.; Cathedral, Cologne, 159 m.; Washington monument, 169 m.; Eiffel tower, 300 m.

COMPARATIVE HEIGHTS OF CELEBRATED STRUCTURES.

AN interesting note, by Mr. Arthur A. Rambaut, on some Japanese clocks lately purchased for the Dublin Science and Art Museum, has been reprinted from the Proceedings of the Royal Dublin Society. These clocks, though differing in other respects, agree in this particular, that the time is recorded, not by a hand rotating about an axis, but by a pointer attached to the weight, which projects through a slit in the front of the clock case. This pointer travels down a scale attached to the front of the clock and thus points out the hour.

[Continued from SUPPLEMENT, No. 704, page 11244.]

THE STRUCTURAL STRENGTH OF SEA-GOING TORPEDO BOAT No. 1.

By Lieut. F. J. DRAKE, U. S. Navy.

STILL WATER STRESSES.

IN Figs. 5, 6, 7, 8, and 9, B S represents the length of L. W. P. to scale 1 inch = 30 feet. B is the bow, and S the stern. The curve, D D, is the curve of buoyancy for a displacement of 117·22 tons at a draught of 5 feet 2½ inches, carrying an equipment of 42·88 tons, which will be the deep load draught when fully equipped for sea.

The curve, W W W, is the curve of weights for deep sea load, and is the sum of the ordinates for weight of hull and lading. Great care was taken in the distribution of the weights of equipment, so as to reduce the limit of irregularity in their intensity to a minimum, which resulted in bringing the body of weight between 40 and 103 feet from the stern. The distribution of coal lies between 40·75 feet and 98·25 feet from the stern, and is equally distributed on both sides of engines and boilers.

The center of gravity of the coal bunkers when full is 1·65 feet below the line of sheer rail at section 45 and 0·032 foot abaft this section.

The moments of the area of these curves about the base line, B S, and middle ordinate at section 45 or 67·5 feet from stern are respectively the same, also their positive and negative values, as follows: M M M represents the curve of bending moments as integrated from the curve of sheering stresses.

SHEERING STRESSES.

Feet from Bow.	Sheering Stress.
15·5 feet.	− 1·92 tons.
42·5 "	+ 8·00 "
51·5 "	+ 2·96 "
60·2 "	+ 4·56 "
74·4 "	− 5·60 "
87·5 "	− 1·04 "
97·2 "	− 9·32 "
124·7 "	+ 2·36 "

It crosses the axis, B S, twice, producing three points of maximum bending moments, one above and two below the axis, showing that the two ends of the boat are subjected to sagging moments, while the middle of the boat has a hogging moment.

ductions have been made for a length of wave of 138 feet:

Radius of rolling circle........ ...	21·96 feet.
Periodic time of the wave.......	5·14 seconds.
Velocity of wave in knots.	18·30
Height of wave................ ..	9 feet.

The center of buoyancy is $\frac{1}{18}$ of her wave length below the plane of flotation. At this depth the diameter of the orbit of a particle of water is 0·3128 foot of the height of wave, and the diameter of the orbit in which her center of gravity revolves is $0.3128 \times 9 = 2.82$ feet, being the height of the effective wave surface, floating passively.

Then the extent to which, during the passage of a wave, her depth of immersion amidships is alternately increased above and diminished below her depth of immersion in smooth water is:

$\frac{9 - 2.82}{2} = 3.09$ feet broadside to wave; but when the torpedo boat rides head to the sea her center of gravity has a mean motion less extensive than in passive heaving, as above stated, the proportion of which is approximately found as follows:

Length of wave surface.............	138 feet.
Coefficient of fineness........	0·37 "
Reduced length......................	51 feet.

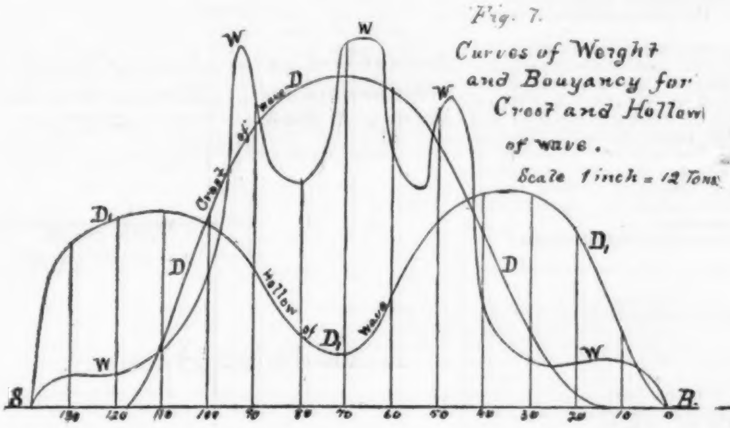


Fig. 7. Curves of Weight and Bouyancy for Crest and Hollow of wave. Scale 1 inch = 12 Tons.

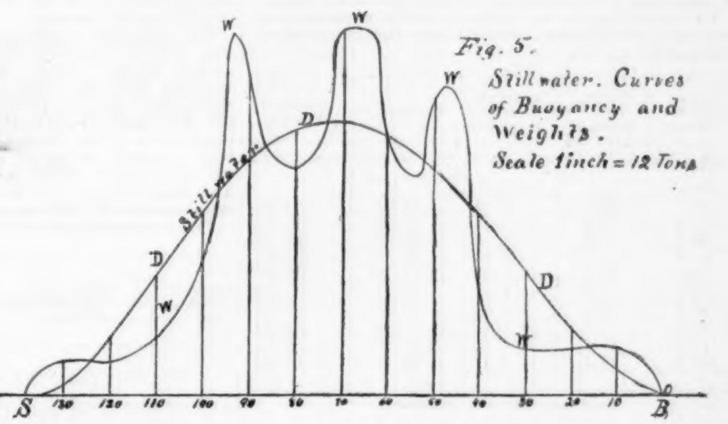


Fig. 5. Still water. Curves of Buoyancy and Weights. Scale 1 inch = 12 Tons

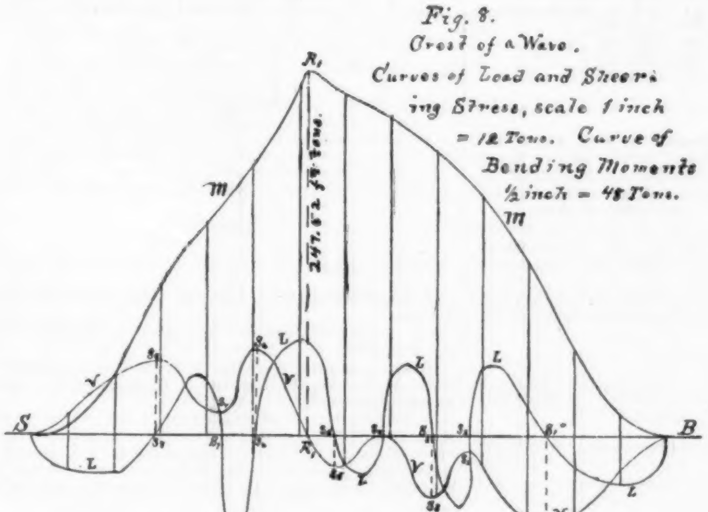


Fig. 8. Crest of a Wave. Curves of Load and Sheering Stress, scale 1 inch = 12 Tons. Curve of Bending Moments ½ inch = 48 Tons.

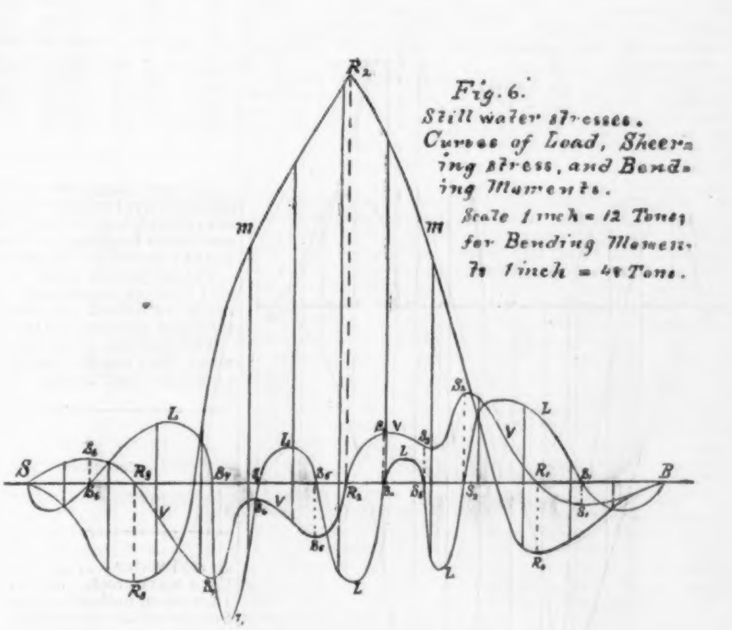


Fig. 6. Still water stresses. Curves of Load, Sheering Stress, and Bending Moments. Scale 1 inch = 12 Tons; for Bending Moments 1 inch = 48 Tons.

areas are equal; their centers of gravity are in the same ordinate. It will be observed that the total weights exceed the limit of buoyancy at five points in the length of the boat, viz., at the bow and stern, also at 46, 65, and 93 feet from the stern, thereby determining the negative or downward forces as shown in the curve of loads.

CURVE OF LOADS.

In Fig. 6, L L L represents the curve of loads to scale and gives the total resultant force acting upon the torpedo boat at any point of her length, and its direction, whether above or below the line, B S, shows the character of the load. At the bow and stern and the three points mentioned the curve of loads is below the axis, B S, showing the weights to be in excess of buoyancy and negative forces at these points.

The curve of loads crosses the axis eight times, which gives eight water-borne sections.

The effect of the boilers and engines is clearly represented by the three negative loops of the curve of loads.

CURVE OF SHEERING STRESSES.

The maximum intensity of the sheering stresses is shown in the curve, V V V, in Fig. 6 at the points, S_1 S_2 S_3, etc., S_8, in which there are three points of reverse racking, as will be seen at R_1 R_2 and R_3. The maximum sheering stresses at S_1 S_2 S_3, etc., are given, with their

At R_1 R_1, 26·5 feet from the bow, the excess of buoyancy over weight amounts to 6·44 tons, with a sagging moment of 25·44 foot tons.

The sum of the moments of downward forces is 164·60 foot tons.

The sum of the moments of upward forces is 661·32 foot tons.

The resultant moment of the bow extremity is negative, having an excess of weight over buoyancy, which is immediately followed by an excess of buoyancy over weight, and a large positive moment, which reaches a second maximum at R_2 R_2, the second point of reverse racking, where the excess of weight over buoyancy is 8 tons, and yet there is no sagging moment, but a hogging one of 143·56 foot tons. The bending moment then decreases, and reaches a third maximum of negative value at R_3 R_3, 23·6 feet from the stern, where the excess of buoyancy over weight is 4 tons, with a sagging moment of 36·24 foot tons.

STRESSES WHEN AMONG WAVES.

In Fig. 7, D D D represents the curve of buoyancy on the crest of a wave, and D_1 D_1 D_1 the curve of buoyancy in the hollow of a wave of her own length, in which equal volumes of displacement were obtained and the same longitudinal position of center of buoyancy as in still water.

From Rankin's formulæ for waves the following de-

The chart corresponding to the reduced length, 51 feet, as the arc of a circle whose circumference is 138 feet, is 40·5 feet.

The proportion then is $\frac{40.5}{51} = 0.794$.

The extent of passive heaving is 2·82 feet broadside to a wave. Therefore, in the present case it will be $2.82 \times 0.794 = 2.24$ feet, which is sufficiently near for the present purpose. And $\frac{9 - 2.24}{2} = 3.38$ feet will be the alternate increase and decrease of depth of immersion amidships riding head to sea.

This limit was taken above and below the L. W. P. in still water for crest and hollow of wave in determining the displacement.

Curve of Loads.—On the crest of the wave, L L L, etc., represents the curve of loads, which it will be observed crosses the neutral axis, B S, at S_1 S_1, S_2 S_2, S_3 S_3, ... S_8 S_8, giving eight water-borne sections. See Fig. 8.

In this curve the excess of buoyancy over weight exceeds that of the *curve of loads* for still water, between 40 and 100 feet from the bow, by 263 per cent., while the excess of weight over buoyancy at the two ends is increased in the same ratio.

This result produces very nearly an opposite effect in the curve of sheering stresses as compared with that for still water.

In Fig. 8, V V V V is the curve of sheering stresses on the crest of a wave. This curve has but one point of reverse racking, R_1 R_1, situated 78 feet from the bow, where it changes from a negative to a positive force.

The maximum intensity of sheering stresses is given in the following table:

Point of Sheering Stresses.	Feet from Bow.	Sheering Stress.
S_1 S_1	25·7	— 7·60
S_2 S_2	43·0	— 1·20
S_3 S_3	50·9	— 5·24
S_4 S_4	61·5	0·00
S_5 S_5	72·2	— 2·84
S_6 S_6	89.4	+ 7 80
S_7 S_7	96·7	+ 2·04
S_8 S_8	111·1	+ 7·04

Curve of Bending Moments.—M M M represents the curve of bending moments to a scale of ⅛ inch = 48 tons.

It will be observed that by the change of position of the upward forces acting upon the torpedo boat on the crest of a wave, as referred to in the curve of loads, a hogging moment is produced at every point in her length, the maximum moment being at 78·1 feet from the bow, when it is 247·52 foot tons, and the excess of buoyancy over weight at the same point is 8 tons.

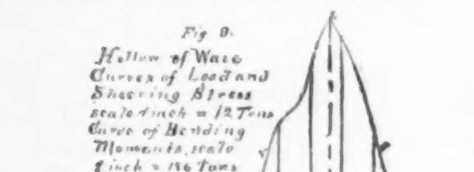
The following is the table of bending moments at the eight water-borne sections and the point of reverse racking:

Distance from the Bow.	Length of Division.	Sheering Stress on Division.	Products.	Bending Moments.
Feet.				
25·7	25·7	— 3·80	— 97·64	— 97·64
43·0	17·3	— 5·28	— 77·36	— 175·00
50·9	7 9	— 3·16	— 24·96	— 199·96
61·5	10·6	— 2·28	— 24 36	— 224·32
72·2	10·7	— 1·40	— 14·96	— 239·28
78·1	5·9	— 1·40	— 8·24	— 247·52*
89·4	11·3	+ 4·48	+ 50·52	— 197·04
96·7	7·3	+ 4·88	+ 35·84	— 161·20
111·1	14·4	+ 4·52	+ 65·08	— 96·12
137·5	26·4	+ 3·64	+ 96·12	— 00·00

* Equals point of reverse racking.

HOLLOW OF A WAVE.

Curve of Loads.—In Fig. 9, L L L L is the curve of loads in which the scale of ordinates is 1 inch = 12 tons, and the neutral axis, B S, 1 inch = 30 feet.



This curve crosses the neutral axis, B S, twice, showing two water-borne sections at 43·1 and 98 feet respectively from the bow.

The excess of weight over buoyancy between 40 and 100 feet from the bow is 52 tons.

Curve of Sheering Stresses.—V V V is the curve of sheering stresses; it has but one point of reverse racking at 70·02 feet from the bow, where it changes from a positive to a negative force.

It has two points of maximum sheering stresses, one at S_1 S_1, 43·1 feet from the bow, equal to + 36·48 tons; the other at S_2 S_2, 98 feet from the bow, of — 43·72 tons.

The following is the table of ordinates for sheering stresses:

Distance from Bow.	Section.	Sheering Stress.	
Feet.			
20	0 to 20 ft.	+ 9·20	
30	20 to 30 "	+ 22·68	
43·1	30 to 43·10 "	+ 36·48	S_1 S_1 water-borne sec.
50	43·1 to 50 "	+ 30·40	
60	50 to 60 "	+ 23·48	
70	60 to 70 "	+ 1·12	
80	70 to 80 "	— 19·96	R_1 R_1 reverse racking: 70·02 feet.
90	80 to 90 "	— 31·96	
98	90 to 98 "	— 43 72	
100	98 to 100 "	— 42 56	S_2 S_2 water-borne sec.
110	100 to 110 "	— 32·56	
120	110 to 120 "	— 19·36	
130	120 to 130 "	— 6·48	
137·5	130 to 137·5 "		

Curve of Bending Moments.—M M M represents the curve of bending moments to a scale of 1 inch = 186 tons.

In the hollow of the wave there is a sagging moment throughout the length of the torpedo boat, except the small portion of 22 feet at the stern, where there is a slight hogging moment.

The maximum sagging moment is 70 feet from the bow, where it reaches 1,263 foot tons at very nearly the middle of her length. This is the greatest stress brought upon the boat, and at this point may future weakness, if any, be looked for between frames 46 and 47. This transverse section passes through the coal bunkers and the forward low pressure cylinders of both engines, and crosses the intercepted portion of the upper deck, where the continuity of deck beams and deck plating is broken (to admit the engines), covering an area of 112·5 square feet.

The following is the table of bending moments:

Distance from Bow.	Length of Division.	Sheering Stress on Division.	Products.	Bending Moments.	
		Tons.	Ft. tons.	Ft. tons.	
20	20	+ 4·60	92·00	92·00	
30	10	+ 15·96	+ 159 60	248·60	
43·1	13·1	+ 29·60	+ 387·76	639·36	First water-borne section.
50	6·9	+ 33·44	+ 230·72	870·08	
60	10	+ 26·96	+ 269·60	1139·68	
70	10	+ 12·28	+ 122·80	1262 48	
70·2			0	1263 00	Point reverse racking.
80	10	— 10·20	— 102·00	1160·48	
90	10	— 25·96	— 259·60	900·88	
98	8	— 37·84	— 302·72	598·16	Second water-borne section.
100	2	— 43·12	— 86 24	511·92	
110	10	— 37·56	— 373·56	+ 138·36	
120	10	— 25·96	— 259·60	— 121·24	
130	10	— 12·92	— 129 20	250·44	
137·5	7·5	— 3·24	— 24·32	274·76	

By these diagrams of stresses in still water and among waves we have a series of results shown in the curves which point out the relative magnitudes of the maximum hogging and sagging stresses in a torpedo boat of this type, so distinct from other classes.

The subjoined table of maximum sheering stresses and bending moments is deduced from the curves already explained as connected with their calculated tables of stresses and moments.

The sheering stress is given in terms of the displacement. The bending moments are given in terms of displacement and length.

Conditions.	Sheering Stress.	Bending Moments.
	Displacement.	Displacement × Length.
In still water	[illegible]	[illegible]
On a wave crest	[illegible]	[illegible]
In a wave hollow	[illegible]	[illegible]
Supported at extremities	[illegible]	[illegible]
Supported at middle	[illegible]	[illegible]

NEUTRAL AXIS OF THE TORPEDO BOAT.

In order to know whether the maximum intensity of the stresses for sheering and bending moments as determined are within the working limits of the material of which the torpedo boat is made, it is necessary to find the tensile stress in tons per square inch on the deck and bottom plating, two points which are farthest from the neutral axis.

The latter was determined from the effective sectional area of each plate liner, angle iron, etc., disposed longitudinally, adding to the longitudinal strength of the torpedo boat. The weakest section was taken between frames 45 and 46.

In order that the result should not err on the unsafe side in computing the effective sectional area, deductions were made for rivet holes, water tight floor, riveting coal bunker fronts, deck plating, and stringers to beams, and for liners, butts, and fastenings, in all 42 per cent.

The remaining 58 per cent., which was taken as representing the effective sectional area, was grouped symmetrically about the middle line of the section as a central axis, thereby forming an equivalent girder as shown in Fig. 10, which is to a reduced scale of $\frac{1}{30}$ in square inches.

The top flange of the girder, Bx, contains the flat of the upper deck plating, etc. = 5·32 square inches. The remaining sections of the web are as follows:

xd, round of deck plating, carlings, etc., to connection with top of coal bunker fronts = 4·48 square inches.

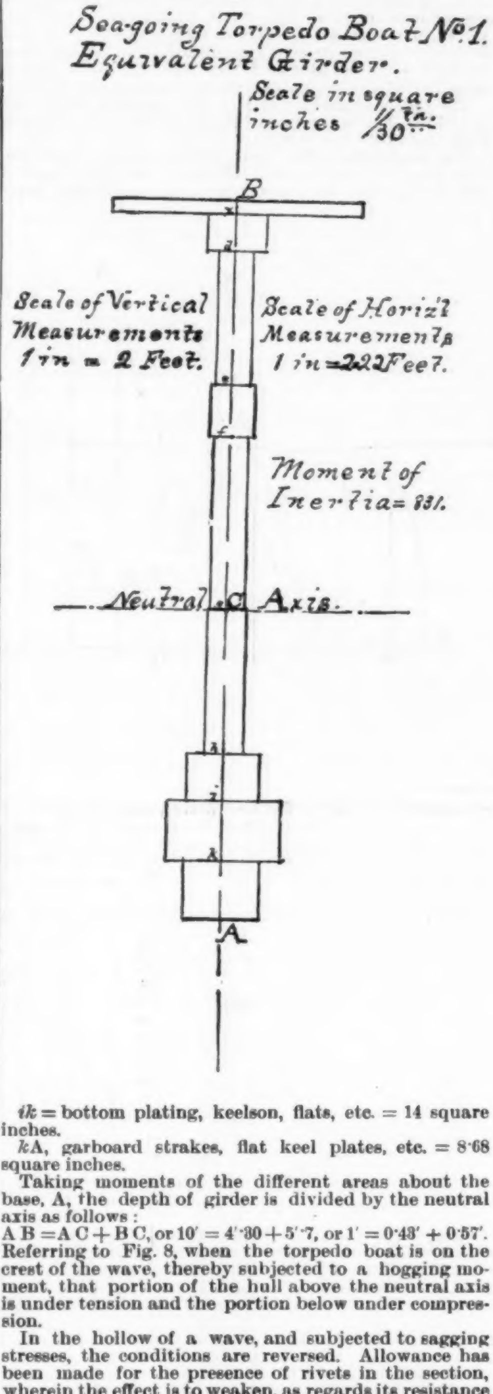
de, round of deck plating to stringer angles and vertical plating of coal bunker fronts = 9·17 square inches.

ef, sheer strake, stringer angles, and vertical plates of coal bunker fronts with horizontal stiffeners = 4·34 square inches.

fg and *gh*, shell plating, vertical section of coal bunker fronts, etc. = 11·34 and 10·36 square inches respectively.

hi, shell plating and coal bunker fronts with intercostal angles, etc. = 6·30 square inches.

Fig. 10.



ik = bottom plating, keelson, flats, etc. = 14 square inches.

*k*A, garboard strakes, flat keel plates, etc. = 8·68 square inches.

Taking moments of the different areas about the base, A, the depth of girder is divided by the neutral axis as follows:

A B = A C + B C, or 10′ = 4′·30 + 5′·7, or 1′ = 0·43′ + 0·57′.

Referring to Fig. 8, when the torpedo boat is on the crest of the wave, thereby subjected to a hogging moment, that portion of the hull above the neutral axis is under tension and the portion below under compression.

In the hollow of a wave, and subjected to sagging stresses, the conditions are reversed. Allowance has been made for the presence of rivets in the section, wherein the effect is to weaken, as regards its resistance to extension, and the reverse when the stress is a compressive one.

The moment of inertia of the effective sectional area about its neutral axis is found to be 831·09 foot units of measurement.

The intensity of the stress on any part of the section is obtained from the formula—

$$\frac{p}{y} = \frac{M}{I}$$ in which the unit of area is a square inch.

p = the stress required.

y = the distance from the neutral axis = the hogging or sagging moment in foot tons.

I = moment of inertia.

Therefore when the torpedo boat is on the crest of a wave it is subjected to a hogging moment of 247·52 foot tons. The moment of inertia of her effective section about the neutral axis is 831·09 foot units.

The tension in tons per square inch on her upper deck plating, which is 5·62 feet above the neutral axis, will be—

$$\frac{p}{y} = \frac{M}{I}$$

$$\therefore p = \frac{My}{I} = \frac{247{\cdot}52 \times 5{\cdot}62}{831{\cdot}09} = 1{\cdot}674 \text{ tons}$$

While the actual tension on this section of the deck from sheer rail to sheer rail is 42 tons.

The compression on the flat keel plates, which are 4·3 feet above the neutral axis, will be:

$$\frac{43}{57} \times 1{\cdot}674 = 1{\cdot}26 \text{ tons per square inch, while the actual}$$

thrust on these plates is 2·84 tons. In the hollow of a wave the greatest sagging stress takes place about this section and amounts to 1,263 foot tons.

The tension in tons per square inch on the flat keel plates will therefore be

$$p = \frac{1263 \times 4{\cdot}304}{831{\cdot}09} = 6{\cdot}541 \text{ tons.}$$

The actual tension on the cross section of these plates is 13·72 tons.

The greatest thrust on the deck plating will be

$$\frac{57}{43} \times 6{\cdot}541 = 8{\cdot}70 \text{ tons per square inch.}$$

FACTOR OF SAFETY.

The mean of elastic limits which I determined from a series of physical tests made upon the material of which the hull of the torpedo boat is composed is 33,600 lb. per square inch, or 15 tons, with an ultimate stress of 27 tons. For compression 14 tons per square inch are accepted as the effective limit of resistance of the shell plating within the proof load.

As sea-going torpedo boats of this class are intended to be constructed so as to be driven into a head sea on occasions of necessity without burying themselves completely, it therefore becomes necessary to know not only the energy stored in the moving mass and the method of variation of the resistance, but also the striking velocity and magnitude of sheering stresses between the crest and hollow of a wave.

To meet the shock of a sea successfully, the resilience must be sufficient to take up the shock without serious deformation of the material, due regard having been given to the form of hull.

It is therefore necessary to make the *elastic* resilience of the material greater than the maximum energy of that portion of the wave displaced by the boat.

The torpedo boat as a moving load in passing through the waves is subjected to a series of shocks whose periodic time is in proportion to the speed of the boat.

Lying head to sea passively, the changes from the hogging to the sagging stresses, which are equivalent to a variation in the moment of reverse racking of 1,511 foot tons nearly, occur at intervals of about 2·6 seconds.

At a maximum speed of 20 knots, head to sea, the period of the wave is reduced to about 2·28.

This makes the interval between hogging and sagging stress, or the period of application of a load of 1,511 foot tons, 1''·14.

In view of this, it is highly essential that the factor of safety in vessels of this type should be considered only under the ratio in which the elastic resilience of the material *exceeds the maximum working load.*

Under tension, the maximum stress is 6·541 tons per square inch on the flat keel plates, as in the hollow of a wave. The elastic limit of the material is 15 tons, and $\frac{15{\cdot}00}{6{\cdot}54} = 2{\cdot}29$ = proof factor of safety. Assuming the factor of safety, according to the distinguished architects, Mr. W. J. M. Rankine, W. John, S. J. P. Thearle, and others, at 5, and accepting 22 tons per square inch, as determined, for the ultimate strength of the galvanized material, the maximum tension on the galvanized structure of the boat should not exceed 4·4 tons per square inch. But under the maximum stress of 6·54 tons per square inch the factor of safety is

$$\frac{22}{6{\cdot}54} = 3{\cdot}36+$$

and under the maximum thrust of 8·7 tons per square inch the factor of safety is $\frac{27{\cdot}00}{8{\cdot}70} = 3{\cdot}10$. Hence for the torpedo boat we have the following results:

Conditions of Load.	Factor of Safety.		Tons per Square Inch.			
			Upper Works.		Flat Keel Plates.	
	Proof.	Working.	Maxim'm Tension on Crest of a Wave.	Maxim'm Thrust in Hollow of a Wave.	Maxim'm Tension in Hollow of a Wave.	Maxim'm Thrust on Crest of a Wave.
Stresses	2·29	3·36	1·67	8·70	6·54	1·26
Thrusts	1·61	3·10	....	....	....	....

From the above results it will be seen that the commonly accepted value of 5 for the factor of safety has been reduced 24 per cent. for the ultimate stress and 38 per cent. for the ultimate thrust.

On account of the length compared with the breadth and the lightness of material, and the distribution of weights, the *proof* factor of safety having a value of not less than 2·5 would have increased the thickness of the flat keel plates to 15 pounds per square foot, and the garboard and stringer plates to 10 pounds each.

EFFICIENCY OF RIVETING.

Of the shell plating all vertical seams were butted, strapped, and treble riveted between bulkheads on frames 27½ and 65½. In treble riveting, alternate rivets in the row nearest the edge were omitted.

All other butt straps were double riveted; zigzag riveting generally was employed throughout.

All longitudinal seams were lapped and double riveted. Double riveted laps and all butt straps were spaced 3⅝ (nearly) diameters with 1⅜ diameters edge margin to outside row for calking.

Maximum Efficiency of Butt Straps.—From a series of experiments which I made upon the galvanized plates for the hull, I found the average reduction in tensile strength of the punched plates to be 5 tons per square inch.

As the diameter of the rivet has a constant value, the only variation in the strength of the plate must be due to *galvanizing and the pitch of the rivets.*

Let t = thickness of plate in inches. Let p = pitch of the rivets = 1·359 inches. Let d = diameter of the rivets = 0·375 inch; then $p - d$ = distance between consecutive rivet holes = 0''·984.

Therefore making allowance for the tensile strength of the plate being reduced from 27 to 22 tons per square inch, then the maximum efficiency which the butt connections have in this case, where the rivets are spaced 3⅝ diameters, will be equal to the product of the ratios of $\frac{p-d}{p}$ and $\frac{22}{27} = \frac{0{\cdot}984}{1{\cdot}359} \times \frac{22}{27} = 0{\cdot}59.$

For the flat keel plates of ¼ inch thick $p = 2''$, $d = \frac{1}{2}''$, and $t = 0''{\cdot}25$.

Then the maximum efficiency of the flat keel plate butt straps double riveted is $\frac{1{\cdot}5}{2} \times \frac{22}{27} = \frac{33{\cdot}00}{54} = 0{\cdot}61.$

And for strength of rivets:

$$0{\cdot}393 \times 24{\cdot}5 = 9{\cdot}62 \text{ tons.}$$

And for strength of plate between rivet holes:

$$22 \times \tfrac{1}{4}\,(2 - \tfrac{1}{2}) = 8{\cdot}25 \text{ tons.}$$

Which shows the efficiency of joint to be

$$\frac{9{\cdot}62}{8{\cdot}25} \times 0{\cdot}61 = 0{\cdot}71.$$

For the maximum thickness of bottom plating of $\frac{5}{16}$ inch having butt straps treble riveted, with alternate rivets omitted in the row nearest the edge of strap, the strength of rivets is

$$\frac{\pi d^2}{4} \times 2\tfrac{1}{2} \times 24{\cdot}5 = 0{\cdot}275 \times 24{\cdot}5 = 6{\cdot}73 \text{ tons.}$$

in which $d = \frac{3}{8}''$, $p = 1''{\cdot}359$, and $t = \frac{5}{16}$ inch thick of plate; and for strength of plate between rivet holes $22 \times \frac{5}{16}\,(1{\cdot}359 - 0{\cdot}375) = 4{\cdot}059$ tons, which shows the efficiency of the joint to be

$$\frac{6{\cdot}73}{4{\cdot}059} \times 0{\cdot}59 = 0{\cdot}978.$$

For double riveted butt straps the strength of rivets is 5·39 tons, and the efficiency of this joint is

$$\frac{5{\cdot}39}{4{\cdot}059} \times 0{\cdot}59 = 0{\cdot}784.$$

In both cases the riveting is stronger than the plate.

The half inch rivets used in flat keel plates, stem and stern posts, and keelson were driven hot. All others were driven cold. All plates were punched after galvanizing. All frames were punched previous to being galvanized.

For lap-jointed work the following percentages were determined as the amount to be added to the calculated weights of plating on account of laps, butt-straps, and liners, for plates 162 inches long and 29 inches in width:

Thickness of Plates.	Diameter of Rivets.	Double Riveted Laps Spaced 3⅝ Diameters.	Double Riveted Butt Straps, 11¼ Diameters Wide.	Treble Riveted Butt Straps, 16¾ Diameters Wide.	Liners Width of Plates.	
in.	in.					
¼	½	9·75	3·85	4·26	5·40	Spacing of frames 18 inches.
$\frac{3}{16}$	⅜	8 44	3·45	3·75	5·38	
⅛	¼	7·15	3·15	3·50	5·25	
$\frac{3}{32}$	$\frac{3}{16}$	6·58	3·00	3·31	5·00	
$\frac{1}{16}$	$\frac{3}{16}$	6·58	3·00	3·31	5·00	

In forming the above table during the construction of the boat, the weight of each plate was taken before and after punching, and the weight of rivets used in the plate, also the amount of flush cutting from the countersunk head removed at final "drawing down." Deducting the latter from the weight of rivets, the difference between the original weight of plate and the total weight of plate and rivets was used as the amount of percentage in weight, as given above.

GALVANIZING.

The effect of galvanizing upon the tensile strength of plates and angles has already been given.

The effect upon the weight and thickness of the material I determined from a series of careful measurements, both in size and weight of plates and angles before and after galvanizing; also the diminished weight due to pickling in the bath preparatory to galvanizing, as follows:

Number of Plates.	Size in Inches.	Weight in Pounds.				
		Original Weight.	After Cleaning and Pickling.	Reduction per Square Foot, Both Sides.	Galvanized.	Increase per Square Foot, Both Sides.
6	165×30×¼	2119·	2093·	0 1298	2168·	0·363
10	165×30×$\frac{7}{32}$	3150·	3106·	0·1290	3229·	0·358
60	165×30×$\frac{3}{16}$	16776·	16518·	0·1291	17241·	0·354
30	165×30×$\frac{5}{32}$	7211·	7079·	0·1292	7441·	0·351
60	165×30×⅛	12352	12086·	0·1289	12790·	0·341
35	93×30×$\frac{3}{32}$	2654·	2559·	0·1288	2783·	0·331
22	93×30×$\frac{1}{16}$	1169·	1130·	0·1290	1271·	0·330
222		45431·		0·9038		2·428
				0·1291 mean.		0·347 = mean

It will be observed from the above data that for thin plating, etc., ¼ inch thick and less, the original weight is diminished 0·1291 pound per square foot, including opposite side, in pickling, while the weight is increased 0·347 pound per square foot, including opposite side, in galvanizing.

The above increase in the weight of shell plating and angles was considered in computing the weight of hull.

The following is the average weight of galvanized angles per foot of length:

2 in.	by 2 in.	by ¼ in.	3·7	pounds.
1¾ in.	by 1¾ in.	by $\frac{3}{16}$ in.	2·2	"
1½ in.	by 1½ in.	by $\frac{3}{16}$ in.	1·48	"
1¼ in.	by 1¼ in.	by $\frac{3}{16}$ in.	1·14	"
1 in.	by 1 in.	by $\frac{3}{16}$ in.	0·78	"

Under these conditions the structural strength of sea-going torpedo boat No. 1 will undoubtedly prove the efficiency of its construction, if future comparisons with European boats are made.

THE INSPECTION OF RIVETED BRIDGE WORK

By CHARLES F. PARKER, M.E., 1884.

RIVETING is an abstruse subject even when taken at its best, that is, when it is done as well as it can be in practice. No one can say with certainty just what stress a rivet in a piece of work is subjected to, because in most cases the conditions are such as to utterly defy analysis. To illustrate: Suppose we have two pieces of wrought iron fastened together by three ⅝ inch rivets. The shearing strength of the iron being 50,000 pounds per square inch, we should expect these rivets to stand 90,150 pounds before giving way, and they would do so if the plates were pinched tightly together so as to bring only a shearing stress into play. But if, as is frequently the case in practice, they are not pinched tightly together, the rivets are strained by a combination of a shear and bend, and it will be impossible to tell just how much they are capable of holding. To cover all such defects the designing engineer must allow a very large margin for safety, usually subjecting a rivet to a shear of not more than 7,500 pounds per square inch; and he must also insist upon rigid inspection in order to detect all bad work and remedy it as far as possible.

The inspector's task is therefore a faultfinding one, and unless he is possessed of an extraordinary amount of tact, or is willing to let poor work pass, he generally manages to get himself ardently disliked by the contractor and his workmen.

Almost the first thing which commends itself to his attention is the matter of loose rivets. A loosely driven rivet has only from two-thirds to seven-eighths of the shearing resistance of one tightly driven, and hence it is extremely important that the holes should be well filled. The method of testing is by striking each rivet a light blow with a hammer, when the loose ones can be easily discovered, either by the sound which they give out or by the hammer appearing to cushion against them. A little practice will render one very expert, and it would be an easy matter to detect bad work if the rivets were left exactly as they were driven. There are tricks in all trades, however, and just here is the place for the riveter to get in one of them if he thinks he will not be caught by the inspector. He does not like to have his rivets condemned because they are loose, and it is a very easy matter to run a calking tool around the edges of those which are so. They will then feel and sound all right, and the mark of the calking tool will not be noticed unless it is especially looked for. Another way of accomplishing the same end, and a far more dangerous one, because it cannot be detected even by an experienced inspector, is to place the "snap" sideways upon the rivet and strike it two or three blows with a sledge. It will then appear to be tight, partly because it is bent and partly because the snap cuts a ridge in the plate and forces the metal against the head. All rivets tightened in this way show this ridge below the heads, but a similar mark will often be made in shaping the head of a perfectly tight rivet, so the inspector cannot condemn work simply because this mark appears. All such work should be regarded with suspicion, however, and a sharp watch kept upon the workmen.

In testing, the inspector should always, if possible, go to the "held up" head. Few inspectors do this, the majority preferring to strike the other side. A rivet may be perfectly tight on the head, while in consequence of poor heating it may be readily moved on the "held up" side. Besides, the riveter cannot tamper with that part of the rivet, and any mark there will show that he has been trying to conceal bad work.

When a rivet is found to be loose, it should be cut out and replaced by one tightly driven, except in some cases where the cutting would do more harm than could be made up for by having it redriven. This would be the case where there are three or more plates which do not assemble accurately, thus not giving a "fair" hole. When the rivet is upset it fills the uneven space, and if an attempt is made to back it out, the plates are strained or torn. In such cases it would be better to allow it to remain.

Almost all text books on the resistance of materials deprecate the drifting of rivet holes because of the weakening effect caused by it. Specifications frequently read: "All rivet holes must be so accurately punched that when the several parts forming one member are assembled together, a rivet $\frac{1}{16}$ of an inch less in diameter than the holes can be entered hot into any hole without reaming or straining the iron by drifts." It is not usual to find work as accurately punched as this, and in most cases a certain amount of drifting is allowed, as the extra strength gained in reaming the holes would not be commensurate to the time spent upon it.

This matter of drifting is, however, a subject of discussion, as some engineers will not allow a drift pin on the work, while others, though not openly approving of them, look upon them as a necessary evil. The whole question resembles that of drilled *versus* punched holes. English engineers condemn the American practice of punching holes as barbarous, and say they should be drilled; while the American engineers retort that they can afford to put a little more metal in the work and still save money on account of the less time consumed. Another defect to be guarded against is that of burned rivets. The only way of avoiding this is by having skilled heaters and watching them closely. There is no way of telling after a rivet has been driven whether it is burned, for the head may look perfectly good while the shank is badly damaged. Sometimes one seemingly perfect will snap off at the

first blow of a sledge almost as if it were tempered steel; whereas if it had not been injured it would have taken twenty or thirty of the same blows to cut it off. The burning of rivets is not always accidental. Often, if the rivet is so long as to more than fill the snap, the heater will "waste" the end; that is to say, he will burn it so badly that it will crumble off. Of course, this also affects that part of the shank which remains, and should be prohibited.

These are the principal points which the inspector of riveting should watch. There are many others which will arise on every piece of work; but they are minor ones, and are, as a rule, easily discovered and the consequent bad work rectified.—*Stevens Indicator.*

[Continued from SUPPLEMENT, No. 704, page 11247.]

SIBLEY COLLEGE LECTURES.—1888-89.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

V. PUMPING MACHINERY: ANCIENT AND MODERN.*

BEFORE proceeding to give an account of the recent improvements referred to in pumping machinery, let us for a moment consider what is required to be done, in order that large volumes of water may be raised in the best possible manner and with the best possible economy.

Among the first things the practical engineer should know, and among the last things he will, after becoming such, forget is that, in handling water within pipes, he has a fluid which, while it is flexible to the greatest extent, and is susceptible of the influence of power or force of greater or less intensity, and while it may be drawn from below and raised to the heights above, can be turned to the right or to the left at will, and while, with a seeming docility which is as flattering as it is deceptive, it bends itself to the will of the engineer; still there are some things it will not do, and which all the complicated appliances of the engineer have as yet failed to compel it to do. When inclosed within chambers and pipes, to an extent that fills them, it will not permit the introduction of an added atom without bursting its bounds. While inclosed within long lines of pipes, it will not suddenly start into motion, or when in motion, suddenly come to a rest, without shocks or strains more or less disastrous; and so, while it seems to be handled with the greatest ease, it is only in the manner it chooses to go, and all mechanical appliances not designed with reference to following these imperative laws are sure to meet trouble, if not disaster. In other words, when an unyielding force meets an unyielding resistance, their coming together means a shock to all about.

The perfection of steam pumping machinery would be to use the steam so that, by cutting it off within the steam cylinder, and by subsequent expansion in the same or other cylinders, its expansive force would be developed to the highest limit and to the most economical extent. When that is done, we have accomplished all that, with our present knowledge of the steam engine, can be done. Having thus perfected the power end of a pump, the next and important thing to do is to connect that power to the pump in such a manner as that it will produce the best results so far as the stability and permanence of the machine and its connections are concerned.

As to the construction of the pump itself, little or nothing need now be said. They differ only in the minor details of their construction; and except for crooked and cramped passages, insufficient valve areas, and improperly constructed valves, the pump itself has little or nothing to do with the action of the water column or the economical use of the steam. The manner in which the steam power is connected to the pump controls the first, and the method in which the steam is expanded controls the latter. It has previously been shown that with the stored-up power in the beam and weighted plunger of the Cornish engine, and in the power stored up in the revolving fly wheel of the crank and fly wheel engine, it is possible to get a good economy in the use of steam. Now, but for the perverse stubbornness in the water itself (and to which I have alluded), it would seem an easy task to make a perfect steam pumping engine, but it is just in such instances that the best laid plans of the engineer often go wrong.

In the Cornish pumping engine, the water in the rising column will not start into motion rapidly or come to a rest suddenly at each end of the stroke of steam piston without serious shocks, unless at a slow speed of the piston; and a slow speed of piston means loss of economy in the use of the steam. In the crank and fly wheel pumping engines, the time at which the water column begins to move, and the varying rate of speed at which it moves during the half stroke of the crank, as well as the time at which its motion ceases, all depend on rigid, unyielding connections which couple the steam cylinder and pump to the revolving fly wheel with its stored-up power, through the medium of a crank and crank shaft; a power which in its movements does not seek to adapt itself to the peculiarities of the column of water within the pipes, but which seeks to overcome them by superior force.

In the duplex direct-acting pump, the water column is connected to the steam cylinder by and through the pump plunger alone, and without the use or intervention of heavy moving parts, or through the positive, unyielding action of cranks, driven by heavy fly wheels. In other words, the only power that is exerted on the water column is the direct elastic power of the steam. When we remember how inelastic and unyielding water is, when confined within pipes, we can well imagine what will be the result of unyielding motion and power when it comes in contact with such an unyielding fluid as is water. To better illustrate the difference in the effect produced by these various kinds of pumping engines, it may be truly said that it would be quite impossible to handle under pressure a long column of water with a crank-moved pump, without the use of a chamber filled with air, also under pressure, on the line, which would by its elasticity serve as a cushion, or buffer, to take up the conflicting blows which take place between the power and the resistance in pumping machinery of this kind, and to reduce them as far as possible in order to insure the safety and stability of the surrounding parts.

As an illustration of the different effect produced by the steam-moved direct-acting pump, it may be said there are now in use pumps of this class exerting over 250 horse power, delivering five million gallons of water in twenty-four hours, through main pipes say thirty inches diameter and fourteen miles long, without the use of an air chamber, and which do the work so quietly, so steadily, and so gently, that a nickel coin set on edge at the extreme end of the pump would not be overthrown by any jar or motion of the pump while it was doing this work.

A still further test of the superiority of this method of moving and controlling long columns of fluids under extreme heavy pressures was made at the time of the introduction of long pipe lines for conveying oil from the wells to the seaboard. After trying various kinds of pumps for forcing the oil through these long pipes, and after having a succession of disasters in the way of burst pipes and leaking joints, it was decided to test the efficiency of the direct-acting duplex steam pump.

These pumps were placed in the various stations along the pipe lines, and after a continued service of many years, have shown their perfect adaptation to that exceptionally hard service. These pumps convey the oil over mountains where at times the coupled lines have been over one hundred miles long between the pumps, and where the pressure on the plunger of the pump sometimes rises to 1,500 lb. per square inch.

Owing, as it has been shown, to the peculiar adaptation of, and the ease with which the direct-acting pump, as described, meets the requirements of a hydraulic engine for raising water, it may be said without hesitation that no pumping engines have ever been constructed which will raise the same quantity of water against the same pressure, with the same weight of metal in its construction, the same inexpensive foundations, the same simplicity of parts, freedom from shocks in the water column, and at an equal low cost of construction and low cost of repairs as now do the modern improved direct-acting duplex steam pumps. A careful consideration of the above statement will reveal the fact that there is omitted in the enumeration of the unequaled combination of good points only one thing to complete the list, and which, if added, would place this class of pumping engines beyond all competition. That one thing is the same economy in the use of steam.

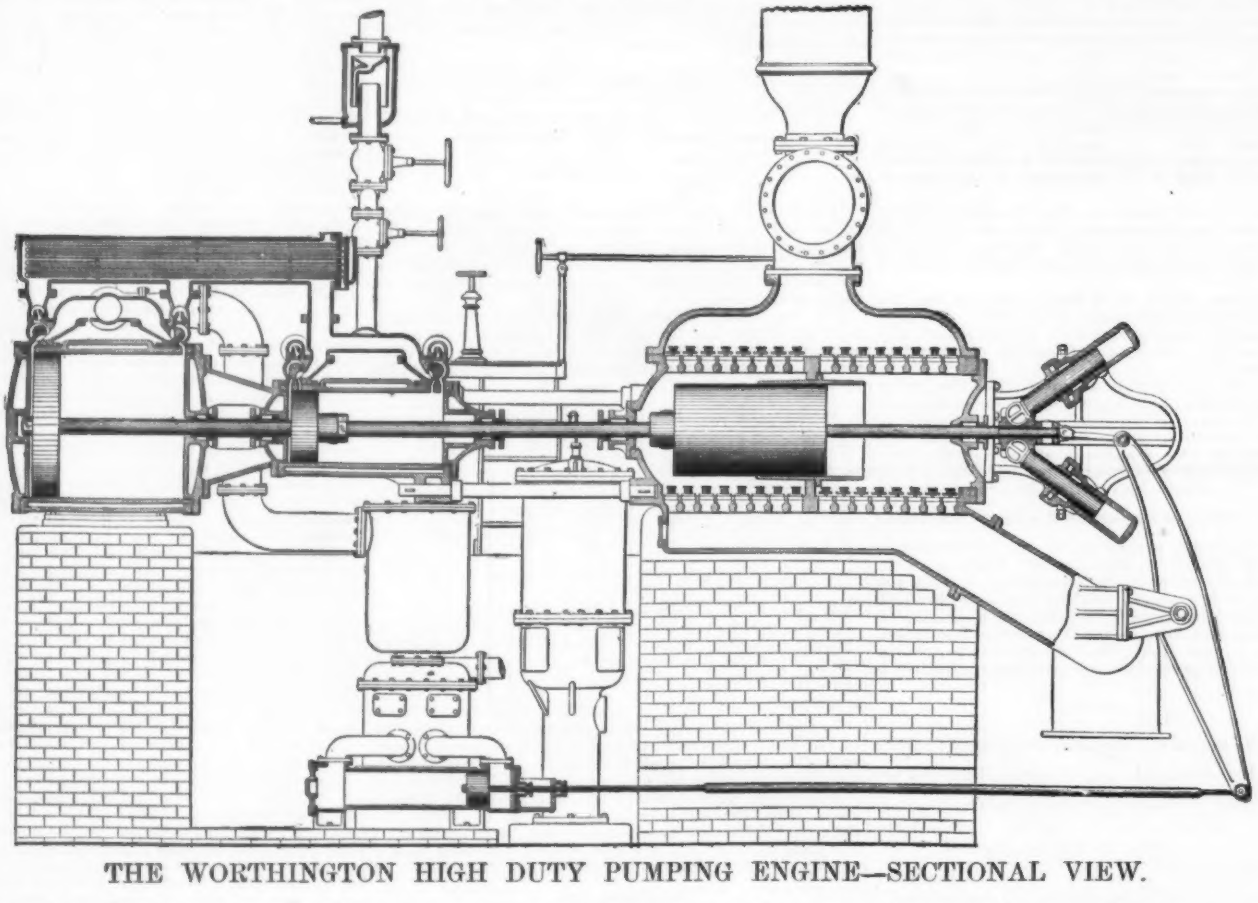
Inasmuch as it would not be possible to use weighted plungers, cranks, and fly wheels in order to bring about this much to be desired result, without entirely destroying some of the most valuable and distinctive features of this class of pumping engines, it has been thought impossible to secure this one lacking improvement of being able to cut off the steam within the steam cylinders, and thus greatly increase the ratio of expansion and the attendant economy of steam, and at the same time preserve a uniform pressure of power on the pump plunger and the same uniform movement of the water column.

To accomplish this much sought for result was left to the genius and invention of the son of the man who first invented the direct-acting steam pump previously spoken of, as "the little pump of the canal boat," and which was the forerunner of the magnificent pumping engines now in use in this and other countries, and which in the simplicity of their construction and precision of action have excited surprise as well as admiration in the minds of all engineers who have seen them in operation and who have noted the results they produce.

It was my purpose at the outset to make the description of this invention the special feature of this paper: to illustrate by drawings and diagrams the wonderful adaptation of the device employed to the end sought, and to show by indicator cards the surprising results it has produced; but the whole subject has widened out to such an extent as that it has already occupied much more of your time than I intended, and I will be now obliged to give somewhat briefly the outline only of the description of an invention which by its novelty, as well as its importance, is worthy of a more extended treatment, and by a more skillful lecturer.

In addition to its recent application in several large pumping plants in this country, it has as well been applied in several recently constructed water works in the vicinity of London, England, where the results obtained have been so remarkable as to awaken much interest among English engineers, several of whom have made careful tests of their performance, the reports of which have recently been added to the engineering literature of the day, and which proves to be very interesting reading.

Returning to the description of the compound condensing direct-acting duplex pump, it will be remembered that the one needed improvement was some device or attachment by which steam power could be



THE WORTHINGTON HIGH DUTY PUMPING ENGINE—SECTIONAL VIEW.

* Delivered before the class of Mechanical Engineering of Sibley College, Cornell University, by J. F. Holloway, Past President of the American Society of Mechanical Engineers, and of the Civil Engineers' Club of Cleveland.

stored up at the beginning of each stroke of the piston, and given out again toward the end, in order to still further promote its economy. Such a device would, if properly constructed, permit the use of high pressure steam at the commencement of each stroke, and of its being cut off during a portion of the stroke; thus enabling less steam to do the same work, and of course with a corresponding saving of fuel.

As illustrating the peculiar adaptation of this kind of pump for handling water, it may be said that an indicator card taken from the water end is practically a parallelogram. In order to produce such a card, in which no irregular lines reveal the irregular action of the power used in driving the pump, it is evident that when driven by the direct force of the steam on the pump plunger, the steam card must also be a parallelogram as well.

Now, were we to introduce steam in such a cylinder at the beginning of its stroke, which was of a much higher pressure than was necessary to move the column of water, the result would be an excessive pressure at that point on the water, which would not only distort the water card and which would be shown by the indicator, but it would as well bring excessive shocks and strains upon the pump and its connecting pipes. On the other hand, to cut off the steam in the cylinder at any point during the stroke of the piston would be to reduce the power below the point necessary to move the water column, and the pump would stop short of its full stroke.

This newly invented and ingenious device, which is intended to permit the cutting off of the steam in the steam cylinder and its subsequent expansion, while at the same time the force exerted by the steam upon the pump plunger shall remain uniform during the entire stroke, may be briefly described as follows: between the area of the air piston and the ram of the accumulator. This difference of areas is a matter of calculation based upon the particular service for which the pump is constructed. The pressure in the air cylinder is controlled by the pressure in the main delivery pipe of the pump, as it is connected to the air chamber on the main delivery. The peculiar and important effect this arrangement has on the operation and success of the "high duty pumping engine" will be shown later on.

Having described briefly the construction of this new and novel attachment to the direct-acting duplex pump, I will now describe as best I can without a model its effect on the operation of the pump.

We will suppose the pump about to begin its outward stroke. At this time the compensating cylinders will be turned so as to point toward the outer end of the pump, with their plungers at the extreme point of their outward stroke, and at an acute angle with the pump plunger rod, and with the full pressure of the accumulator load pushing them against the advance of the pump plunger. As the pump plunger begins its outward stroke, each forward movement it makes changes the angle of the compensating plungers, until at one-half stroke the two plungers will stand exactly opposite each other and at right angles with the pump plungers, and of course in a position where they can neither retard nor advance the movement of the plunger.

Now, as the pump plunger passes the center of its stroke, the compensating plungers, being as before said attached to the crosshead of the pump plunger rod, begin to turn in an opposite direction from which they started, and by degrees, owing to the increasing acuteness of the angle they make with the plunger rod, they begin to exert a power to push the pump plunger along, whereas, before and up to the half stroke, they we have under consideration. You see that the admission line is straight, and perpendicular to the line of pressure; this is owing to the fact that in pumping engines of the kind we are describing there is a slight pause at the end of each stroke, which not only allows the pump valves to seat themselves quietly, but it as well fills up the clearances and steam ports to the full steam pressure before the piston starts. In this diagram XX represents the line of the atmosphere and YY the line of the zero pressure. The power exerted in this cylinder up to the point of cut-off, and from that to the end of the stroke, is shown by the line $l\ m\ n\ o\ p\ q\ r\ s\ t\ u\ v$, which is the steam line of one stroke of the piston. The return stroke is shown by the exhaust and compression line, $k\ j\ i\ h\ g\ f\ e\ d\ c\ b\ a$. The resulting pressure in this cylinder will be the pressure above the line Y at each of the ordinates, less the back pressure at the same ordinate. If we take this resultant pressure, and apply it to the same number of ordinates all of which shall start from one common base line, we will have a curved line which resembles Fig. 2, in which the line $a'\ b'\ c'\ d'\ e'\ f'\ g'\ h'\ i'\ j'\ k'$ will show the available steam pressure at each part of the stroke of the piston.

In Fig. 3 we obtain by the same process the line of pressure in the expanding steam cylinder, on the same number of ordinates, and from each ordinate of which we must, as before, subtract the back pressure above zero pressure. When we have done so, we will have the total pressure line of the expanding steam cylinder as shown in Fig. 4. In order that we may make a comparison of the pressure in the expanding cylinder with the high pressure card, we must multiply the total pressure shown on each ordinate by the ratio of the areas of the two cylinders, which in this case is four to one. This will produce the curved line shown

FIG. 1.

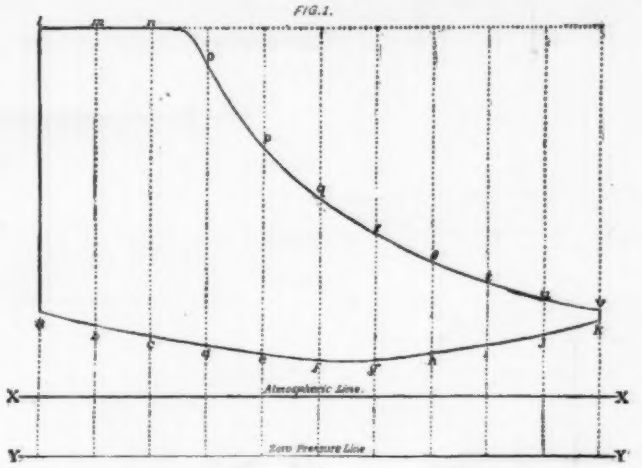


FIG. 2.

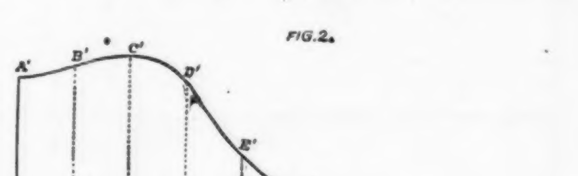


FIG. 3.

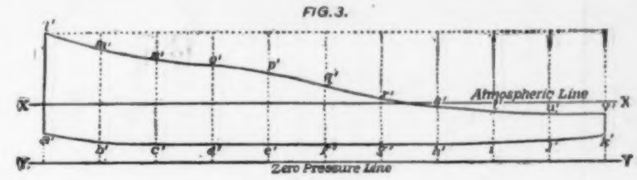


FIG. 4.

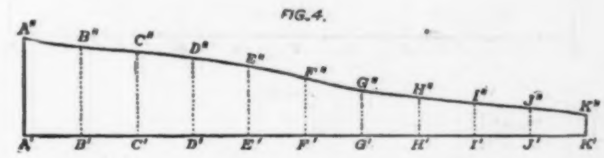
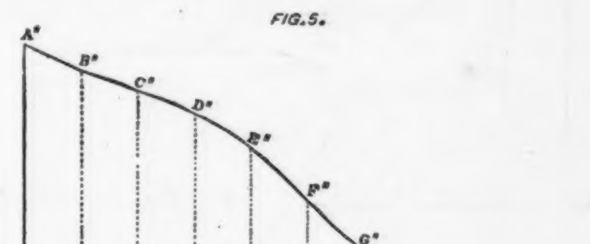


FIG. 5.



To the ordinary compound direct-acting steam pump as usually built there is attached a plunger rod which projects through the outer end of the pump chamber, and around which there is the usual stuffing box for packing the same. On the end of this plunger rod is fastened a crosshead which moves in guides that are bolted on the outer end of the pump. On this crosshead, and opposite to each other, are semicircular recesses.

On the guide plates are cast two journal boxes, one above and the other below the plunger rod, both equidistant from it, and at a point equal to the half stroke of the crosshead. In these journal boxes are hung two short cylinders on trunnions, which permit the cylinders to swing backward and forward, in unison with the motion of the plunger rod. Within these swinging cylinders are plungers, or rams, which pass through a stuffing box on the end of the cylinder, and on their outer end they have a rounded projection which fits in the semicircular recesses in the crosshead, and consequently, as the crosshead moves in or out of the pump, it carries with it these two plungers, which in turn tilt the cylinders backward and forward.

These swinging cylinders are called "compensating cylinders," and they are filled with water, except when the pumping engines are used on oil lines, when they are filled with oil.

The pressure on the rams within the compensating cylinders is produced by connecting the compensating cylinders through their hollow trunnions with an accumulator, the ram of which moves up and down, as the rams of the compensating cylinders move in and out. The accumulator used is of the differential type, that is, it has below a small cylinder filled with oil or water, in which its ram moves, while above it has a much larger cylinder filled with air. On the top of the ram of the accumulator is an enlarged piston head which fits closely in the air cylinder. So it will be seen that the pressure per square inch on the ram of the accumulator will be the pressure of the air in the air cylinder per square inch multiplied by the difference resisted the movement of the plunger. This pushing force increases constantly until at the extreme end of the outward stroke, and when the accumulator plungers are, as at the beginning, at their most acute angle, they exert their greatest force in helping to aid the pump plunger in its outward movement. It is, perhaps, unnecessary to add that the return stroke of the pump is made under precisely the same conditions as the previous stroke.

If we were to convert the movements of the compensating plungers into a diagram which would illustrate the power they receive and give out, we would have a curved line having a point at the half stroke in which there would be no power exerted, while at one end would be shown a line of resistance above that zero line, which would be the exact result of that resistance at each point in the first half of the stroke: and it would also show on the last half of the stroke the same curve of power given out again. The peculiar shape of this curve is the result of carefully calculated arrangement of the details of construction, and it can be made to conform very close to the curve of the pressure line in the steam cylinder at almost any point of steam cut-off.

Having now considered the pump end of a direct-acting steam pump to which there is attached this new device for obtaining a high rate of fuel economy, we will now turn our attention to the behavior of the steam in the steam end of such a pump. We will assume that the pump is driven by compound cylinders, in which the area of the expanding cylinder is four times that of the high pressure cylinder. In attempting to describe the action of the steam force exerted on a direct-acting pump, I am embarrassed by the fact that I cannot produce before you drawings on the blackboard that will have to any considerable extent the accurate outlines of indicator cards. So you will be obliged to believe rather what I say than what I show.

Fig. 1 represents an indicator card taken from the high pressure cylinders of such a pumping engine as on Fig. 5. Now that we have the line of pressure of each steam cylinder brought to the same basis, we can add them both together and find at once what is the total pressure, or power, that both the steam pistons exert during each stroke of the pump, and also just what proportion of that power is exerted at each particular part of each stroke. This adding together of all the forces of a steam compound condensing engine, under the conditions previously described, will produce a card as shown in Fig. 6, a figure which at first glance would seem to be the farthest possible curve from what is required to move a pump plunger which in its effect on a water column is to show a card "vertical at each end, and parallel on each side." It was for the purpose of producing this much to be desired, although seemingly impossible, result, that the high duty attachment was invented, and, as I hope to show, it has accomplished.

In order that I may the better explain how this is brought about, we will draw a figure which shall represent the pressure of water on the pump above the atmosphere line, as well as the pressure, or as it is best known, the suction line below the atmosphere line, the total of which will be shown on Fig. 9, Fig. 8 being omitted as simply showing how these combined pressures are obtained.

We see in Fig. 9 the result we wish to produce, and in Fig. 6 the means we have of producing this result; and, as it must be remembered, by a piston which is connected directly to the pump plunger, without the intervention of cranks, shafts, or fly wheels. In order to make a graphic illustration of the difficulties to be overcome, as well as the means employed to overcome them, we will on top of this line of the water card pressures, and on the same base line, draw the power or propulsion line, so that we can see how they fit each other.

This is shown by Fig. 11, in which $a\ w\ w\ k$ are the outline of the water load or pressure on the pump, or, as we may say, the resistance which is to be overcome, and $a\ a'\ k'\ k$ is the outline of the force exercised by the

steam cylinders during the same stroke as was shown by Fig. 6. The intermediate letters show the steam power exercised at each part of the stroke, *f' f''* being the half stroke of the pump. In looking on this arrangement of the two diagrams, it will be seen that at the beginning of the stroke of the pump the steam pressure is largely in excess of what is required to move the water, while at the end of the stroke it is far below what will be required to do so, and that it is only at the half stroke that the steam pressure and water resistance are equal, and that, under the conditions as shown, that is the only point where they would meet on equal terms. To put this high pressure of steam on the pump plunger direct would at once and by a sudden jump raise the water pressure far above the point shown, and with a shock the result of which it would be hard to estimate; while the fall of the steam pressure after it passes the center of the stroke would soon bring the pump plunger to a stop, which by its suddenness would produce a shock not unlike that at the beginning of the stroke.

Leaving for the time being this somewhat puzzling problem, we will again refer to the action of compensating cylinders, of an area of plunger and under a pressure of water that would adapt them to a pump operating under the pressure of steam and water resistance, as shown by the previously given figures. This will be graphically shown by Fig. 7, in which the line A B is a neutral or no pressure line, and the ordinates *a b c d e f g h i j k* are equal divisions of the stroke corresponding with the ordinates shown on the steam pressure cards, *f* being in both instances at the half stroke of the pump. The figures shown below the pressure diagram represent the position of the plunger cylinders at the beginning of the stroke, at one-quarter, one-half, three-quarters, and full stroke, and it also shows what is the effect of the influence exerted by these cylinders at these varying points on the stroke of the pump.

At the beginning of the stroke, *a' l'*, and when the accumulating plungers are at their outer stroke, it will take an amount of power equal to *a' l'* to push the plungers of the compensating cylinders in, against the pressure that is on the end of them; as the plungers are driven in, the angle of the inclination of the plunger to the center line of motion increases, and it takes less power to push them in, and as a consequence the line of the resistance is less and less at each ordinate, until we arrive at the half stroke, where the plungers standing at ninety degrees, each being opposite the other, they are at a neutral line, where they exert no influence on the progress of the pump plunger in any direction; but as the plunger moves on, the compensating plungers acted on by the pressure of the accumulator begin to press outward, and as they leave the center perpendicular line they begin to exert an influence in helping to push the pump plunger along, which influence constantly increases until the plunger arrives at the outer end of its stroke, when the plungers of the compensating cylinders give out their greatest force, and which is exactly the force put into them at the beginning of the stroke. This line of resistance and of impulse can be varied by changing certain features, of the construction, but, as shown in the diagram, it is calculated to suit the steam pressure, and cut off, of the steam pump we have undertaken to describe.

Having constructed another and new line of curves which show a retarding as well as an advancing effect on the power brought to bear on the pump, we will now trace its influence, by placing this curve on the same water card as we did the steam propulsion curve. This brings us back to Fig. 11, in which the line *a k* takes the place of the line *a b*, Fig. 7. Above and below this base line, we construct the same curved line as is shown in Fig. 7, and which crossing the same number of ordinates as have the other cards, shows exactly on each ordinate the influence it exerts on the pump at that particular point of its stroke. With this diagram before us, in which is seen first the amount of power required to move the water column at a steady, uniform pressure through one stroke of the pump, and in which we have the steam pressure line which is to move it, and also the line of useful effect of the compensating cylinder, we will now examine what is the combined effect of all these forces.

We will assume that the left hand vertical line is the beginning of an outward stroke of the pump, just as we have assumed for a previous outward stroke. We see at the very start that the line *a w* is the amount of power required to move the water, but we have the line *a w a''* as the steam power we have put on the pump at this point, and we see that the power inclosed within the lines *w a'' b'' c'' d'' e'' f* is just so much more power than we want. Now, if we look at the lower left hand corner, we will see that the space inclosed between the lines *a a' b' c' d' e' f* and *e d c b a* represents the amount of steam it takes to push in the plungers of the accumulating cylinder, and it adds just that amount of resistance to the advance of the plunger. At *f' f''* we have arrived at the half stroke, and here we find the steam pressure is just equal to the resistance of the load, or head of water on the pump; but as we pass this point on to the end of the stroke, we find that the area inclosed within the lines *f' w k' j' i' h' g'* represents the amount of power which by reason of the expansion of the steam (which in the pumping engine described is sixteen to one) falls below what is required to do the work. It is at this point that the compensating cylinders come to the rescue, and give out the power which by reason of the high steam used at

FIG. 6.

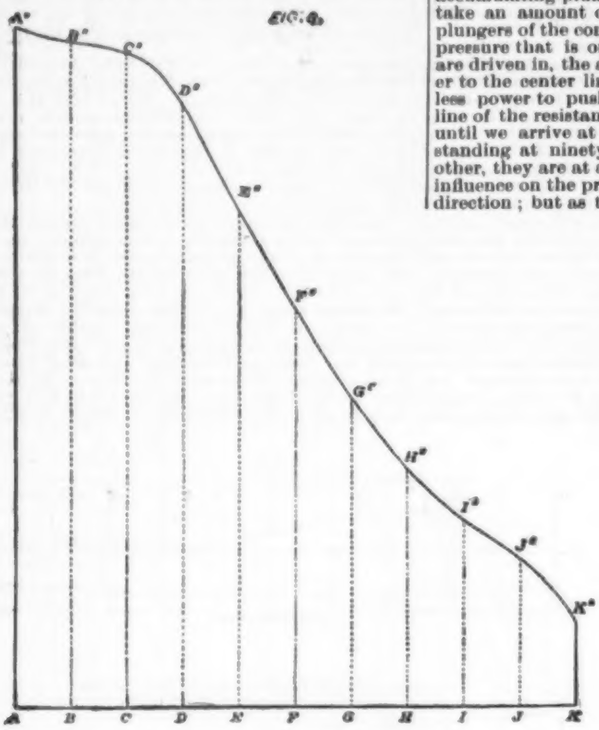


FIG. 7.

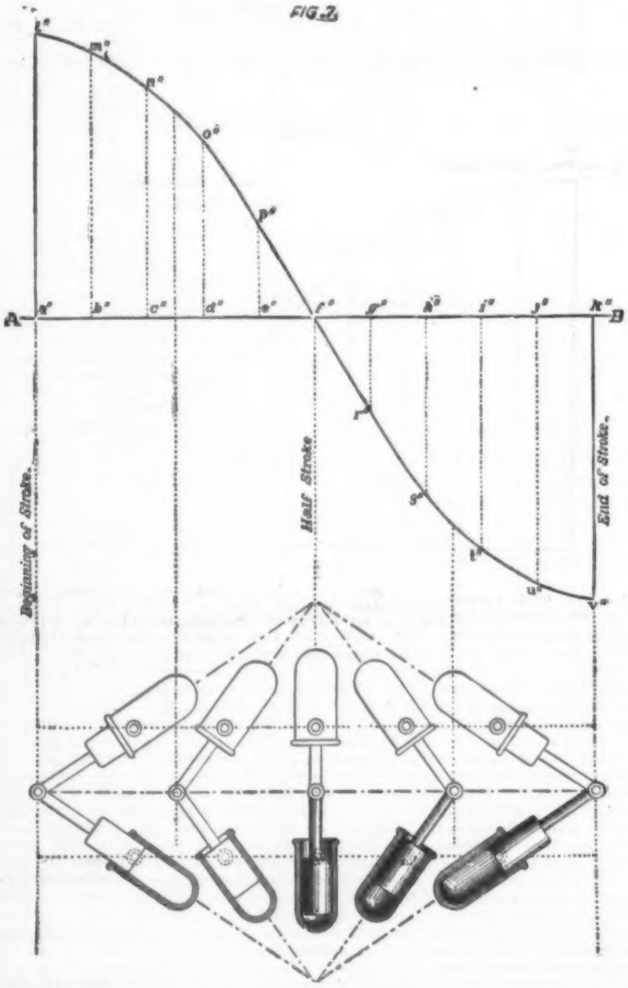


FIG. 9.

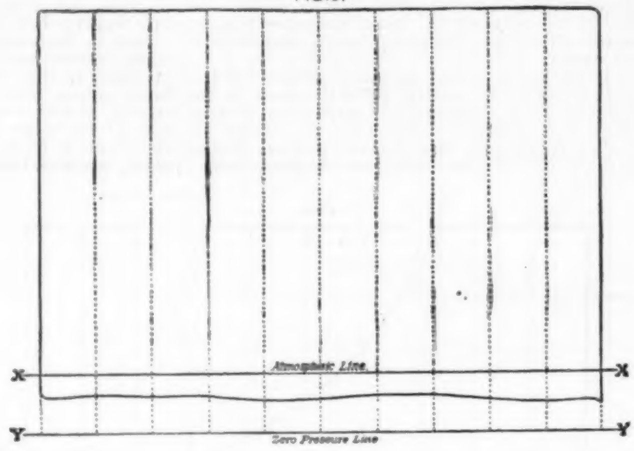
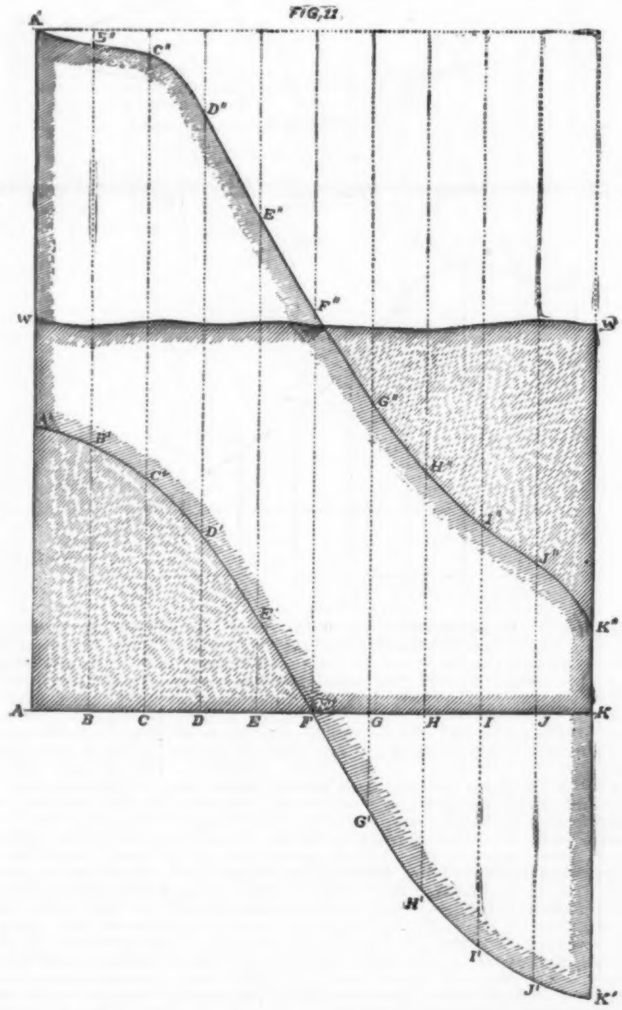


FIG. 11.



the beginning of the stroke was stored up in them; and the space inclosed within the lines *f g h i j k* and *k' j' i' h' g' f'* represent the stored-up power they now give out.

As the diagram is now constructed, the space inclosed between the two curved lines would represent the total net power exerted by the steam direct, as well as through the compensating cylinders, while the space inclosed within the parallelogram represents the resistance to be overcome in moving the water column. Now, if you will measure the length of any one of these ordinates between the curved lines, and which represents the power exercised at that particular part of the stroke, you will find that it exceeds but a very little the resistance of the pump plunger at the same point; the excess of the power being just what is required to keep up the speed of the pump.

While I have, perhaps, described this new and beautiful invention with a minuteness that was unnecessary, I have done so under the impression that there are many persons who look upon these engines when in use, who have no clear idea of the functions performed by the compensating cylinders; and who know of the exceedingly high duty they give, but without an idea as to how such a result is brought about; and for the further reason that the literature on this subject is, as yet, very meager.

In addition to the surprising manner in which this "high duty attachment" fulfills the seemingly last and only want of the direct-acting steam pump, to enable it to become the steam pumping engine of the future, there are other reasons why the use of compensating cylinders is exceedingly desirable. While it has been shown they perform equally well the functions of heavy fly wheels, in distributing the power applied equally through the entire length of the stroke, they do so by using far less material in their construction, and by occupying far less space. There are now pumping engines in use in which the compensating cylinders and their attachments do not weigh 4,000 pounds, and where it would require in order to produce equally satisfactory results in a rotating engine, a fly wheel which would have to be twenty feet in diameter and weigh 100,000 pounds.

Another and equally important feature connected with the use of compensating cylinders is that they produce equally good results when the pump is moving at low speeds as when moving at high speeds, while it is well known that when a fly wheel is employed in connection with pumping, it only produces its best results when run at the one particular speed for which it was designed, and when for any reason the pump is run at a slower speed, the usefulness of the pump is impaired just in proportion as the speed decreases. There is also in the use of the device described an element of safety which is of much value. In a fly wheel pump, if at any time when the pump is working up to its maximum speed an accident takes place, such as the bursting of a pipe or the blowing out of a joint, and the pressure is suddenly released, the fly wheel, by reason of the mass of metal in its rim, and with its stored-up power, instantly starts off at a speed which, unchecked by the attending engineer, would soon produce disaster. When compensating cylinders are used, they derive their power through the accumulator, which in turn is connected with and derives its power from the pressure in the main delivery pipe. Now, if the pressure in the main pipes should suddenly drop by reason of a breaking of pipes, the pumping engine would at once stop, for the reason that it has no mass of metal in motion to impel it forward, and for the further reason that the power of the accumulator would be gone and the action of its own valves would shut off the steam.

There are other features connected with the details of the construction and attachment of these compensating cylinders which further illustrate the ingenuity of their invention and their peculiar adaptation to supply the long-felt want of some contrivance by which to use steam in the class of pumps referred to, at its utmost economy. But I have occupied your time far beyond what I had in mind at the beginning. My apology is that, aside from the fascination of the subject, its novelty, as well as its usefulness, there has never before, so far as I have known, been published any description of this invention, that undertook to give with any degree of minuteness of illustrated description the principles involved in the construction and operation of "the Worthington high duty attachment" as applied to direct-acting steam pumping engines as they are now being built in Europe and America. Besides, it is a rare combination of events that permits us of this generation to witness the beginning, growth, and culmination of an invention which relates to an art or process so old that the genesis thereof has long been lost, but which through all ages has enlisted the thought and study of the ablest minds, but in which it was left to a man of our time to originate, and his immediate successors to perfect, a mechanism to produce these long sought for results, which promises to revolutionize all the old methods of raising water by the aid of steam.

And it should be as well a matter of gratification as of pride to all, to remember that for all this we are indebted to American schools and American engineers.

THE AMERICAN ENGINEERS IN ENGLAND.

THE American engineers who recently went over to the Paris exhibition were entertained by the mayor of Liverpool, June 6. On the 7th, two parties were conveyed by special trains to the Crewe Locomotive Works of the London and North-Western Railway and the Horwich Locomotive Works of the Lancashire and Yorkshire Railway respectively. The works at Crewe have been so often described that any detailed description of them is unnecessary, and they could only be hurriedly gone through by the visitors, who, however, were deeply interested in all they saw, and at the close of the inspection they were entertained at lunch by the company.

The works, however, at Horwich are entirely new, and, in fact, are scarcely yet completed in every department. The building of these works was commenced in 1886, and they are still in an incomplete condition. The land inclosed for the works includes 85 acres, and the covered area of workshops is 13½ acres. The workshops comprise offices, general stores (with gallery), boiler shop, smithy, forge, steel foundry, iron and chain foundries, boiler house, brass foundry, tin and copper smiths' shops, telegraph, mill wrights', joiners', and pattern makers' shops (with gallery), and pattern store; fitting, points and crossings, and signal shops; spring smithy, erecting shops, engine shed, paint shop, chain testing shop, and chain smithy. The carriage of materials from stores and work to their several shops is done by means of tramways, 18 inch gauge, of which there are five miles, the heavy work being drawn by small locomotive engines specially built for the purpose. The departments which were of most interest to the visitors were the boiler shop, steel foundry, fitting and erecting shops, and of these it will be interesting to give a few details. The boiler shop, consisting of a well lighted building, 364 feet long by 111 feet wide, and fitted with a pair of hydraulic pumps and accumulator, two large fixed hydraulic riveters for boiler work, each having hydraulic overhead crane for lifting boilers when riveting, three portable hydraulic riveters on swing cranes, bolted to walls and columns, and three overhead traveling cranes.

In addition, the ordinary machine tools of a boiler shop are provided, together with special machines for drilling, etc. The steel foundry, 150 feet long by 111 feet wide, is fitted with two Siemens-Martin regenerative furnaces, having a high-level tramway for carrying the ladle and a narrow-gauge tramway beneath for mould trolleys. A tramway runs through to the forge and rolling mills. The fitting shop, which is 400 feet long by 111 feet wide, is fitted up with a large number of special machines for dealing with locomotive work, including a large milling tool for cutting out crank axle webs, crank axle lathes, milling, planing, and slotting machines.

These are driven by two wall engines placed at the end of the shop, giving motion by means of bevel gearing to four ranges of shafting running longitudinally and to three 5 ton high-speed rope-jib traveling cranes, which control the principal heavy machines. The erecting shop is 1,520 feet long by 118 feet wide. This shop has been arranged for the repairs of existing and the building of new engines and tenders, and is supplied with twenty 30 ton overhead power cranes driven by wall engines. Access for the engines to the center positions of this long shop is obtained by two traverses. Wheel lathes are placed at various positions for conveniently dealing with wheels taken from engines under repairs.

At the close of the inspection, luncheon was provided by the directors of the Lancashire and Yorkshire Railway Co. In addition to the American engineers, there were present Mr. Daniel Adamson, Mr. Thomas Ashbury (secretary of the Manchester reception committee of the Institute of Civil Engineers), Mr. C. E. Fletcher, Mr. J. Knowles, Mr. W. Radford, Major Hale (American consul in Manchester), Mr. W. Thorley (general manager of the Lancashire and Yorkshire Railway Co.), and Mr. J. A. F. Aspinall (chief mechanical engineer) Luncheon over, ten minutes was devoted to speech making of a complimentary character.

The party then proceeded to a special train, by which they were conveyed to Manchester, and the afternoon was devoted to visits to the Owens College, the Lancashire and Yorkshire Railway Co.'s carriage works at Newton Heath, the Salford Corporation sewage works, and other places of interest.

In the evening, the American engineers and the ladies who accompanied them were received by the mayor and mayoress, and subsequently entertained by the Manchester reception committee of the Institution of Civil Engineers at a banquet presided over by the mayor at the town hall. The company numbered about 200.

A large party of the American engineers inspected the Salford and Barton portion of the Manchester Ship Canal on June 8. They were accompanied by Mr. W. Radford, chairman, and Mr. T. Ashbury, secretary, of the Manchester reception committee; Mr. S. R. Platt, representing the directors of the Ship Canal Company; Mr. Leader Williams, engineer; Mr. Walker, contractor; Mr. E. H. Carbutt, of the Iron and Steel Institute; Mr. W. Goldthorpe, and other gentlemen. Thanks to the contractor, Mr. Walker, every facility was provided, and the weather being fine, the works were seen to great advantage. The visitors were first of all shown over the dock works, which were fully explained by Mr. Leader Williams, who, having spoken of the natural advantages to be obtained here, expressed the opinion that the docks would be the cheapest ever made. Leaving Salford, the party were taken to Pomona, where they had an opportunity of seeing dock construction in the earlier stages. From Pomona the train conveying the visitors passed on to Barton, Mr. Williams explaining the works as it proceeded, and directing special attention to a long, deep cutting effected by a single excavator since Christmas. At Barton, of course, interest centered mainly upon the swing aqueduct scheme. The difficulties of the engineer in the first instance were obvious; and Mr. Williams, at the close of a very lucid explanation of his methods of meeting those difficulties, was rewarded with a round of applause. The train now passed on some distance beyond Barton, and on the way attention was specially directed to the lock works at Barton and Irlam. Incidentally Mr. Williams stated that the company had to deal with five lines of railway which would be carried over at a very high level. The new railways would be completed, tested by the government authorities, and opened six months before they discharged the old lines. In the same way the old aqueduct at Barton would be retained until the new one was ready. On the return to the Salford docks, Dr. Emery, of Brooklyn, said they wished to record their thanks for their reception, and he called upon Mr. Hunt, of Pittsburg, to propose a resolution to that effect. Mr. Hunt said he knew he expressed the sentiments of every one of the American engineers in asserting that they had had an enjoyable and instructive morning. In fact, from an engineering point of view, it had been one of the events of their lives to see and learn all about the work upon the ship canal. They were deeply indebted to Mr. Walker, also to Mr. Leader Williams, for the courtesies extended to them all along the route. He moved a vote of thanks to those gentlemen and to the directors, and also to Mr. T. Ashbury, the indefatigable secretary of the reception committee. Mr. Carbutt, who seconded, said the Manchester Ship Canal was the largest work that was going on in England at the present time. The motion having been carried with three cheers and a "tiger," Mr. S. R. Platt acknowledged the compliment on behalf of the directors, who said they knew they were going on in the right way, and the knowledge gave them great encouragement in their undertaking. They were very pleased to see the American engineers, and he hoped the time was not far distant when visitors from their side of the Atlantic would be brought by steamer all the way from New York to Manchester. Mr. Walker also briefly acknowledged the vote of thanks.

In the afternoon the Americans to the number of over 100 ladies and gentlemen were the guests of the reception committee at a luncheon at the Grand Hotel. Mr. Radford presided, and he and Mr. Ashbury gave expression to kind wishes for the success of the tour in England. Mr. Kent, for the Americans, said their reception so far had exceeded all their expectations, and they were full of gratitude to their English brethren.

The American engineers attended service in Westminster Abbey, and were afterward conducted round the building by Dean Bradley, who delivered an address in Henry VII.'s Chapel on the sacred and historical associations of the abbey.

In the afternoon the visitors attended a reception by Sir John Coode, president of the Institution of Civil Engineers, at Great George Street, Westminster.

The following gentlemen were especially welcomed by name as representing various branches of the profession in America: Mr. D. J. Whittmore, past president of the Society of Civil Engineers; Mr. H. R. Towne, president of the Society of Mechanical Engineers; Professor Elihu Thomson, president of the Society of Electrical Engineers; Professor R. H. Thurston, of Cornell University; Dr. C. E. Emery and Mr. T. C. Clarke. The name of Mr. A. E. Hunt was also mentioned, although that gentleman could not be present. After cordially welcoming the guests generally, the president read an address of welcome on behalf of the council.

Professor Thurston, in reply, cordially thanked the institution for the hospitality which the visitors were enjoying, exceeding as it did anything they could have imagined. They who had done so much in the new world had come over to see what the later work in the old world had been. The occasion was truly memorable, and could not fail to become historical. For the first time they had the spectacle of a great body of members of all branches of the profession coming across the seas to meet their brethren not only of Great Britain, but also of the whole world. He looked upon that meeting as an assurance that when engineers had advanced civilization a little further, all Christendom would be more and more united in brotherly bonds, and legislatures would govern solely in accordance with the true interests of the people. On behalf of the whole profession in America, he tendered to the members of the Institute the heartiest thanks for the hospitality of which they were the gratified and grateful recipients.

The president mentioned that copies of the address would be sent to each of the four engineering institutes in America, and the proceedings terminated.

GAS SCALE.

By JAMES ASHER.

MY device tells ratio of gas bulk to normal. Use it on Galileo's air thermometer—glass tube ending in bulb full of air. Liquid bead in tube is index. Place is due to air pressure and temperature.

Graduate tube after twice reading barometer and thermometer. Suppose, by calculation, you find gas fills 1026 thousandths of space at standard. Suppose it next fills 974. Mark place of index each time. Call upper 1026 and lower 974. Divide space into 52 parts, continuing divisions on tube. Make future scales by comparison.

To correct gas to standard pressure and temperature: Multiply by 1000 and divide by reading.

Example: Jar holds 290·1 c. c. of gas; my scale shows 967; find bulk at standard.

$$\text{Solution:}\quad \frac{290100}{967} = 300 \text{ c. c.}$$

P stands for pressure; T, temperature; and B, bulk readings in my equations. Barometer and thermometer have milligrade scales of my device, with many advantages. Standard point in barometer is 1000. Space between absolute zero and melting point of ice is divided into 1000° on thermometer.

$$(1)\quad \frac{P}{T} = \frac{1000}{B}$$

$$(2)\ \therefore P = \frac{1000\,T}{B}$$

$$(3)\ \text{and } T = \frac{B\,P}{1000}$$

You can use instrument as barometer.

Example: Thermometer is at 910·8° milligrade; gas scale, 1012; find pressure. Substituting in equation (2)

$$P = \frac{1000 \times 910{\cdot}8}{1012} = 900 \text{ thousandths of standard.}$$

Example of use as thermometer: Gas scale is at 1100; barometer, 930; find temperature. Substituting in (3)

$$T = \frac{1100 \times 930}{1000} = 1023^{\circ}\text{ M.}$$

Four more instruments may have my gas scale.

2. Babinet's baroscope, improved. Tube dips into colored glycerine in bottle after passing through air-tight cork. Blow into bottle, then liquid will rise in tube. Babinet used water. I prefer glycerine, which is neither liable to evaporate nor freeze.

3. Drebbel's air thermometer. Tube has bulb full of air at upper end. Lower dips into colored water.

4. Adie's sympiesometer. Wide, shut end of tube is full of air. Lower part bent up as cup holding glycerine.

5. Vidi's aneroid barometer unexhausted. Thin, corrugated lid of air-tight box moves hand.

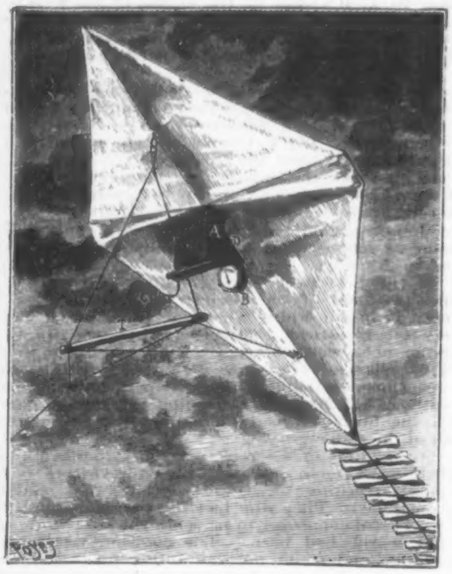
Strathroy, Ontario, Canada.

SCIENTIFIC RECREATIONS.

KITE PHOTOGRAPHY.

DURING the course of the year 1888, we announced that a skillful amateur, Mr. Arthur Batut, had constructed at Enlaure a kite provided with a photographic apparatus by means of which he had obtained some very interesting preliminary results. We encouraged the operator to persevere in his experiments, and are glad that we can now make known the important progress that he has made.

The engraving shows the exact arrangement of the

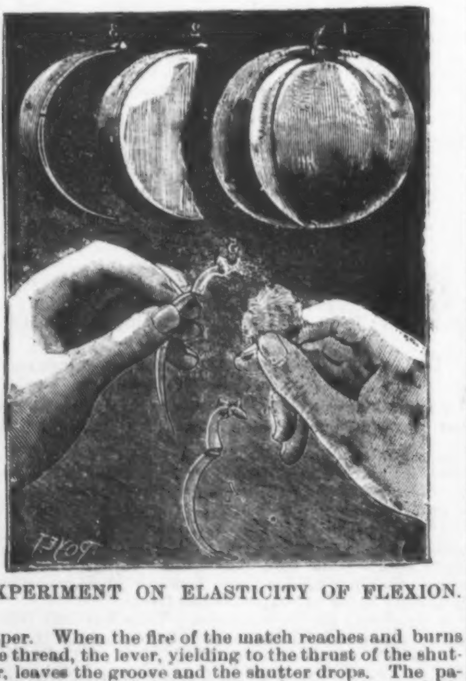


A PHOTOGRAPHIC KITE.

photographic kite. This latter, which is lozenge shaped, is provided with a long tail which gives it perfect stability in the air. The small camera, A, is fixed to the wooden rib of the kite by a triangular support, D. The photographic apparatus is provided with a shutter which is actuated by means of a punk slow match, C, that sets fire to a thread when the combustion has proceeded as far as to the upper part of the match. The string to which the kite is attached is connected with a trapeze, T, properly arranged, so that the solar rays can enter the objective freely.

A registering aneroid barometer, B, is fixed to the upper part of the support, D, so that the operator may know the altitude to which the kite has risen above the ground. The barometer used by Mr. Batut is very ingenious. It constitutes a photographic registering apparatus which operates at the same time that the camera does. It is inclosed in a light-proof box. An aperture, closed by a shutter, is uncovered through the burning of a match at the same time that the photographic apparatus operates. At the moment the aperture is uncovered, the luminous rays strike the dial and print the shadow of the two needles (mechanism and index needles) upon a piece of sensitized paper with which the dial is provided.

The shutter of the photographic apparatus is a simple "guillotine" with a square aperture. The wood, which is very light, is actuated by two strong rubber bands, and its extremity is covered with parchment, which, on entering the grooves, prevents all effects of rebounding. The catch of the shutter consists of a wooden lever fixed in the center by a screw. One end of this closes the groove through which the shutter is to pass. The other extremity is held by a thread which traverses one of the ends of a punk slow match. Under this thread the operator places a folded strip of



EXPERIMENT ON ELASTICITY OF FLEXION.

paper. When the fire of the match reaches and burns the thread, the lever, yielding to the thrust of the shutter, leaves the groove and the shutter drops. The paper falling toward the ground at the same time unfolds and announces to the operator that he can haul in the kite.

Mr. Batut's kite is eight feet in length. The photographic apparatus weighs thirty-eight ounces, and the Steinheil objective with which it is provided is of four inch focus.

ELASTICITY OF FLEXION.

On a former occasion we described some curious methods of cutting apples. On this subject one of our readers communicates to us an amusing experiment in physics without apparatus that may be classed in the chapter on elasticity of flexion.

Take an apple (Fig. 1) and remove a thin slice from it (Fig. 2), and peel off the skin in such a way as to leave it of a certain thickness (Fig. 3). Take care to leave a small portion of the stem at the top, and bend the fragment in two, as seen in Fig. 4. If the object thus prepared be held between the thumb and forefinger, and the skin be gently squeezed after previously raising it at right angles (Fig. 5), the upper part will be made to jerk back quickly; and, when the pressure is removed, it will move forward to its prior position by virtue of the elasticity developed. When these motions are made to occur in succession, the skin descends and rises after the manner of a hen picking up food. If the skin has been properly cut, and a piece of bread be presented to it, one would imagine he saw a bird pecking at the latter.

This experiment, when it is a success, is very amusing, especially if care be taken to have a little chat with the hen. It may be made to perform all the motions of a hen pecking, drinking, or apparently answering yes to questions addressed to it.

CONCAVE AND CONVEX MIRRORS.

When we began taking a course in physics at the Bonaparte (now the Condorcet) Lyceum, it sometimes happened that, in the drawings figured upon the board, we confounded concave with convex mirrors, and *vice versa*. Mr. Felix Hemont, who was our professor at the time, gave us a mnemonic method of avoiding such confusion. "The concave mirror," said he, "recalls to you the idea of *cavity*. Think of a man who is bending forward and looking in the direction of the concavity. His body will assume the form of a *concave* mirror. On the contrary, think of a person whom some one is *vexing*. He straightens up, throws his head back and chest out, and takes the form of a *convex* mirror." This reminiscence of our youth came back to our mind upon finding at a printseller's the two amusing caricatures that we reproduce herewith. The first (Fig. 1) represents a solicitor whom an usher is, so to speak, *concaving* by announcing to him that his request is to be granted. The second (Fig. 2) shows a solicitor whom one is *vexing*, and who throws himself back upon hearing the words that dismiss him, the door being closed in his face. We must be pardoned for giving these bad plays on words; but we are persuaded that those of our young readers who peruse this will, after seeing the accompanying engravings, always recall the form of concave and convex mirrors and lenses; and they will feel obliged to us in their examinations. Mnemonics is not always a subject to be scorned.

The elongation and shortening of figures is illustrated in another of our engravings, in which 1 is a normal photographic portrait, 2 the same individual elongated by mirror, and 3 the same person shortened by mirror.

CURIOUS WAY OF CUTTING AN ORANGE.

One of our Brussels readers, Mr. Bovie, recently sent us an orange of which the skin was very curiously cut.

FIG. 1.—A CURIOUSLY CUT ORANGE.

Fig. 1, from a photograph, gives the exact appearance of it. The two halves of the orange are held by strips of the cut skin solely. Fig. 2 represents (in their different phases, 1, 2, 3, and 4) the operations that must be performed in order to obtain this wonderful result, and the successive incisions that must be made with a sharp penknife in a fine and smooth-skinned orange. We begin by making the incisions shown in No. 1, and then, suc-

1. Photo portrait. 2. The same lengthened. 3. The same shortened.

FIG. 1.—THE CONCAVE SOLICITOR.

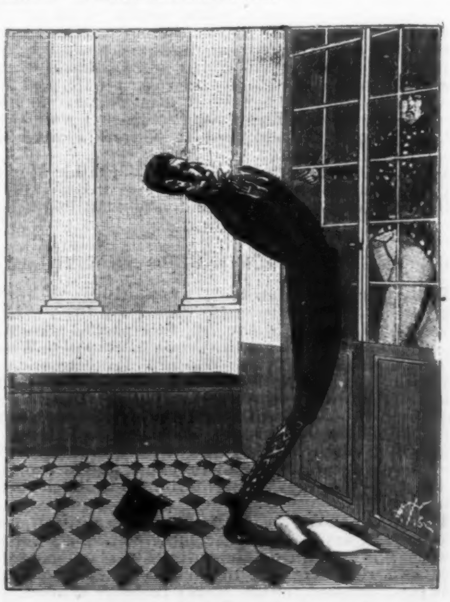


FIG. 2.—THE CONVEX SOLICITOR.

(From two old caricatures.)

cessively, those in No. 2 and No. 3. In measure as the strips are cut, they are raised, and finally an incision, interrupted at each strip, is made in the skin all around the center of the orange. It is through this incision that we must proceed to divide the orange into two

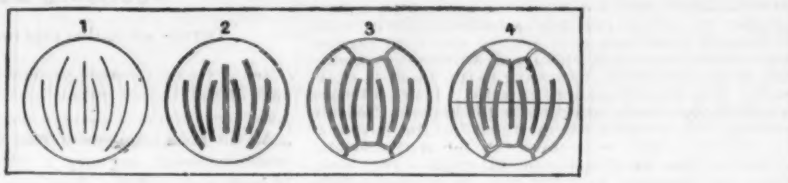


FIG. 2.—THE VARIOUS INCISIONS TO BE MADE IN THE ORANGE SKIN.

parts, and this final operation is certainly the most delicate one.

A CARD CONVERTED INTO A CHAIN.

It is possible to convert a playing card into a continuous chain about four and a quarter feet in length, and that, too, by means of a penknife and a pair of scissors. It is true that the operation is somewhat complicated, but those of our readers who will proceed exactly as follows will easily succeed in performing it.

Let us take an old playing card, say the seven of spades; the question is to transform it, without addition to or subtraction from it, so as to give it the form of a graceful chain, as seen in the figure.

The following are the various phases of the operation:

1. By means of a penknife split the lateral edges, A and B, in two, to a depth of 0·08 of an inch. As the card is made up of several layers of paper, the operation will be facilitated by slightly moistening the two edges to be opened.

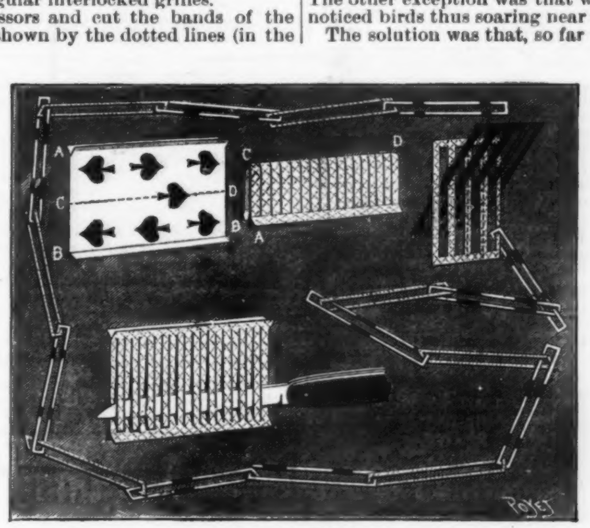
2. Turn back to the right and left the edges, A and B, thus separated, and endeavor to obtain a perfectly rectilinear fold.

3. Bend the card double in the direction of the median line, C D.

4. By means of scissors slit the card according to lines at right angles with the fold, C D, and spaced about 0·08 of an inch apart. These slits should not extend beyond the folds formed by the turning back of the edges, and the bands thus formed will be about 0·08 of an inch in length.

5. Spread the card out upon a table and introduce a knife alternately above and below the bands, so as to cut them according to the line formed by the fold at the edges. Do the same for the other side of the card, but take care here that the knife passes *over* the bands under which it had just passed. In this way there will be formed two rectangular interlocked grilles.

6. Now take the scissors and cut the bands of the card in the direction shown by the dotted lines (in the



A CARD CONVERTED INTO A CHAIN.

block grille). At every section thus made there will be seen to fall a link of the chain that it was a question of forming—each link being connected with its two neighbors, and the whole forming a continuous chain.—*La Nature.*

THE SOARING OF BIRDS.*

So much for sails. Now I want to make some suggestions, or suggest some queries, as to the *skimming* flight of birds, in reference to which a good deal of fresh observation has been possible during the voyage.

You perhaps recollect that when the British Association was at Glasgow, you asked me to put into writing, briefly, as a paper for your section, some remarks on this subject which I had made to you in conversation, but that, owing to my hasty departure to attend the trial of H. M. S. Shah, I omitted to do this.

I had better briefly recite the above particulars here in order to make more clear the bearing of the new observations we (I and Tower) have made.

The view was that when a bird skims or soars on quiescent wings, without descending and without loss of speed, the action must depend on the circumstance that the bird had fallen in with or selected a region where the air was ascending with a sufficient speed.

In still air, the bird, if at a sufficient height, could continue to travel with a steady speed, using his extended wings as a sort of descending inclined plane, the propelling force depending on the angle of the plane and on the equivalent of "slip," that is to say, on the excess of the angle of actual descent compared with the angle of the inclined plane.

The steady speed would be attained when the weight of the bird and the sines of the angle of the plane = the bird's *air resistance*, including skin friction of wings—in fact, one might say = simply the skin friction of the whole area, for the bird's lines are fine enough to justify this statement, since there is no wave-making to be done, and indeed experiment shows that the statement is true for "fish-formed" bodies moving wholly and deeply immersed in water. Of course the bird's angle of actual descent is greater than that of the quasi-inclined plane, owing to the equivalent of "slip" in the wings.

Under these simultaneously acting and correlated conditions there is of course—or probably—some total angle of descent which enables the bird to minimize his rate of approach to the earth in still air.

If when there is a wind the configuration of the ground or any other circumstances can produce a local ascent of air more rapid than the bird's minimum rate of descent when soaring in still air, he may continue to soar indefinitely by keeping in the region where the air is thus ascending.

Now, in most cases where one sees birds "soaring," it is easy to see that they have plainly selected such a region, and for a long time I felt confident that the only two even apparent exceptions I had encountered were such as to *prove* not to *invalidate* the rule.

One of these exceptions was that once, when the sea in Torbay was in a state of glassy calm, I noticed a large gull thus soaring at some distance from the shore—watching it with a pair of binoculars, so that I was sure of the quiescence of the wings.

But here the riddle was at once solved by the observation of what I had not at first noticed—the dark trace of the front line of a fresh sea breeze advancing all across the bay.

Such an advance with a definitely marked front, encountering an extended body of quiescent air, involved of course an ascent of air in the region of the encounter, and this was where the bird was soaring. The other exception was that when at sea I had often noticed birds thus soaring near the ship.

The solution was that, so far as I had then noticed, the birds always selected a region to leeward of the ship, where the eddies created by the rush of air past her hull, etc., might readily have created local ascending currents.

The new exceptions we have seen since we have approached the Cape entirely set these two solutions at defiance.

The first exception we noticed was in the flight of some albatrosses. We were sailing and steaming (at low speed, being short of coal), nearly due east in the latitude of the Cape, with the wind light and variable abaft the beam, and with a well-marked southwest swell of about 8 to 9 seconds period, and varying from 3 or 4 feet to 8 or 9 feet from hollow to crest. The speed of such waves would be from 24 to 27 knots.

Under these conditions the birds seemed to soar almost *ad libitum* both in direction and in speed; now starting aloft with scarcely, if any, apparent loss of speed; now skimming along close to the water, with the tip of one or other wing almost touching the surface for long distances, indeed now and then actually touching it.

The birds were so large that the action could be clearly noted by the naked eye even at considerable distances; but we also watched them telescopically, and assured ourselves of the correctness of our observations. The action was the more remarkable owing to the lightness of the wind, which sometimes barely moved our sails, as we traveled only 5 knots before it, by help of the screw.

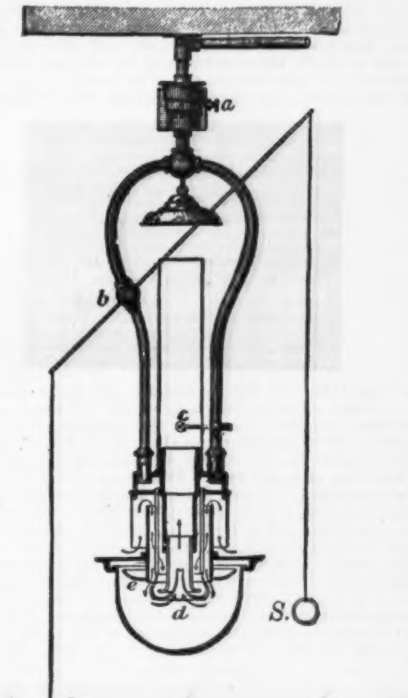
After long consideration the only explanation of at all a rational kind which presented itself was the following, which indeed presents the action of a *vera causa*, and one which was very often certainly in accordance with the birds' visible movements, though it was often also impossible either to assert or to deny the accordance; and anyhow the question arises, Is the *vera causa* sufficient? I will try to trace its measure.

When a wave is say of 10 feet in height and say 10 seconds period (a case near enough to ours to form the basis of a quantitative illustration), the length of the wave from crest to crest is just 500 feet, the half of which space, or 250, the wave of course traverses in 5 seconds, and assuming the wave to be traveling in a calm, it must happen approximately that during the lapse of this 5 seconds the air which at the commencement of the interval lay in the lowest part of the trough has been lifted to the level of the crest, or must have risen 10 feet, so that its mean speed of ascent has been 2 feet per second (10 feet in 5 seconds). And since (as is well known) the maximum speed of an harmonic motion is $\frac{\pi}{2}$ times, or nearly 1½ times its mean speed, it follows that along the side of the wave at its mid-height the air must approximately be ascending at the rate of 3 feet per second, and if the bird were so to steer its course and regulate its speed as to conserve this position, he would have the advantage of a virtual upward air current having that speed.

* Extract from a letter of the late William Froude to Sir W. Thomson, of February 5, 1878, received after Mr. Froude's death. Reprinted from the Proceedings of the Royal Society of Edinburgh, March 19, 1888.—*Nature.*

A NEW FORM OF REGENERATIVE GAS LAMP.

FROM the time when Mr. Frederick Siemens first introduced regenerative gas burners, now ten years ago, down to the present day, this method of burning gas for illuminating purposes has been adopted all over the world, and has come to the assistance of the gas companies by illustrating the fact that, with proper appliances, gas can produce the same brilliant effects as are ordinarily produced by means of electricity, at much less expense both as regards first cost and working. We would explain that in regenerative lamps the heat which is usually wasted in ordinary burners is to a great extent returned to the flame. The manner in which this result is brought about is by intercepting, by means of a regenerator, the heat passing away with the products of combustion, and applying the heat thus saved to raise the temperature of the air which feeds the flame, thus increasing the temperature of the



latter and its illuminating power; for it may be admitted that the higher the temperature of a body rendered incandescent by heat, the greater is the proportion of light rays emitted out of the total amount of energy radiated. This being the case, the amount of heat carried from such a source of illumination to the surrounding atmosphere by conduction and convection must be less than in the case of a burner consuming the same quantity of gas burning at a lower temperature, which circumstance, combined with the well-known economy resulting from the use of these burners, accounts to a great extent for the popularity which regenerative lamps have attained.

Mr. Frederick Siemens has lately introduced a new form of regenerative gas lamp, which we understand is highly efficient, and is in consequence being largely adopted; its construction is shown in the accompanying diagram. It is known as the Siemens inverted type, and is produced in various ornamental designs, which have been much admired. After passing through the governor, A, and the tap, *b*, the gas enters an annular casing; in the lower portion of this, a number of small tubes are fixed, forming the burner, from which tubes the gas passes out in separate streams. By this means combustion of a very perfect character takes place, as the air is directed round each separate stream of gas, and thus enabled to combine most intimately with it. Within the circle of small tubes is a trumpet-shaped porcelain tube, *d*, and around the outside and inside of this the gas burns downward and slightly upward, as indicated by arrows, thus producing a steady, powerful flame of beautiful appearance. This porcelain tube forms the lower portion of the chimney, around which is placed the regenerator. The products of combustion, in passing away, heat the regenerator by conduction, through the metal of the same; and the air, passing upward and downward between its metallic surfaces, as also indicated by arrows

in the diagram, carries the heat back to the flame. The lamp is closed below by a glass globe, which, however, need not be removed for lighting, as a flash light is provided for that purpose.

These lamps are made of different sizes, with a consumption varying from 10 to 40 cubic feet of gas per hour; with London gas they give a light of from ten to twelve candles per cubic foot consumed per hour, which is from four to five times as much as is obtained with ordinary burners. It would have been easy to arrange the lamp we have just described so as to produce a much higher result than that given above; but, to produce this effect, the air supplying the burner would have to be passed through small channels, which would be liable to be partly closed up by oxidation, and thus, by reducing the air supply, cause the lamp to smoke, whereas the Siemens lamp has been specially designed to provide against this unpleasantness, to which regenerative gas lamps are more or less liable.—*Nature.*

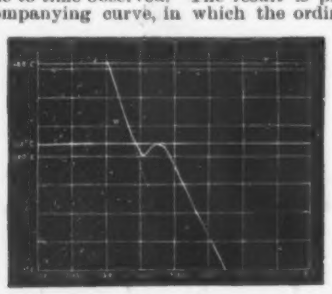
RECALESCENCE OF IRON.*

By Dr. J. HOPKINSON, F.R.S.

PROF. BARRETT has observed that, if an iron wire be heated to a bright redness and then be allowed to cool, this cooling does not go on continuously, but that after the wire has sunk to a very dull red it suddenly becomes brighter and then continues to cool down. He surmised that the temperture at which this occurs is the temperature at which the iron ceases to be magnetizable. In repeating Prof. Barrett's experiments I found no difficulty in obtaining the phenomenon with hard steel wire, but I failed to observe it in the case of soft iron wire or in the case of manganese steel wire.

It appeared to be of interest to determine the actual temperature at which the phenomenon occurred and also the amount of heat which was liberated. Although other explanations of the phenomenon have been offered, there can never, I think, have been much doubt that it was due to the liberation of heat owing to some change in the material, and not due to any change in the conductivity or emissive power. My method of experiment was exceedingly simple. I took a cylinder of hard steel 6·3 centimeters long and 5·1 centimeters diameter, cut a groove in it, and wrapped in the groove a copper wire insulated with asbestos.

The cylinder was wrapped in a large number of coverings of asbestos paper to retard its cooling; the whole was then heated to a bright redness in a gas furnace, was taken from the furnace and allowed to cool in the open air, the resistance of the copper wire being from time to time observed. The result is plotted in the accompanying curve, in which the ordinates are



the logarithms of the increments of resistance above the resistance at the temperature of the room, and the abscissæ are the times. If the specific heat of the material were constant and the rate of loss of heat were proportional to the excess of temperature, the curve would be a straight line. It will be observed that below a certain point this is very nearly the case, but that there is a remarkable wave in the curve. The temperature was observed to be falling rapidly, then to be suddenly retarded, next to increase, then again to fall. The temperature reached in the first descent was 680° C. The temperature to which the iron subsequently ascends is 712° C. The temperature at which another sample of hard steel ceased to be magnetic, determined in the same way by the resistance of a copper coil, was found to be 690° C. This shows that within the limits of errors of observation the temperature of recalescence is that at which the material ceases to be magnetic. This curve gives the material for determining the quantity of heat liberated. The dotted lines in the curve show the continuation of the first and second parts of the curve; the horizontal distance between these approximately represents the time during which the material was giving out heat without fall of temperature. After the bend in the curve the temperature is falling at the rate of 0·21° C. per second. The distance between the two curves is 810 seconds. It follows that the heat liberated in recalescence of this sample is 173 times the heat liberated when the iron falls in temperature 1° C. With the same sample I have also observed an ascending curve of temperature. There is in this case no reduction of temperature at the point of recalescence, but there is a very substantial reduction in the rate at which the temperature rises.—*Electrician.*

DETERMINING LITHIA.

By A. CARNOT.

THE presence of lithia has been recognized in a considerable number of mineral waters, especially in those rich in alkaline chlorides and carbonates. The methods used to effect its determination leave much to be desired, some on account of their inaccuracy and others on account of the complication and length of the analytical operations. The spectroscope furnishes most valuable indications for the qualitative detection of lithia on account of the extreme sensitiveness of the reaction, but a comparison of the intensity of the spectral rays gives only a doubtful approximation as to the proportion of the metal, especially when it exceeds a few milligrms. per liter.

The reagent which the author employs is ammonium fluoride. It is found in commerce, but it requires to be purified, as it contains silico-fluoride in considerable quantity. For this purpose a few grms. of the salt are dissolved in a small volume of water, a double volume of ammonia is added, the mixture is heated to a boil for a few seconds, let cool, filtered, and washed with ammonia. The silica is thus eliminated, and we have the fluoride in a strong ammoniacal solution. It is kept either in a covered platinum crucible or in a stoppered glass, where it may be left some days without undergoing any change. If there are in solution at most some decigrms. of a lithium salt, with quantities of other alkaline salts not more than ten or fifteen times greater, the author proceeds as follows: The solution is reduced to a few c. c. in a tared platinum capsule, ammonium fluoride is added, and an excess of ammonia up to 15 to 20 c. c., according to the quantity of the salts. It is well mixed and let settle. There is formed a white gelatinous precipitate of lithium fluoride, scarcely visible and adhering in part to the bottom of the capsule. This is complete by the next morning. Almost all the liquid is decanted through a very small filter and replaced by a few c. c. of ammonia water with ammonium fluoride. It is stirred up with a platinum spatula and let settle. Soon after a second and a third decantation are made in the same manner and the filter is washed with a few drops of the same reagent. All the soluble alkaline salts are thus removed, and we have, in part on the filter and in part in the capsule, all the lithium salt contaminated merely with ammonia and ammonium fluoride.

The volatile matters are expelled by heating very gently, the filter is burnt, its ash is treated with a few drops of dilute sulphuric acid, and all the liquid is collected in the tared capsule. It is evaporated and gently heated until acid vapors cease to appear, and the neutral lithium sulphate is weighed.

To take account of the solubility of lithium fluoride in the ammoniacal liquid we measure the total volume of the filtrate, which generally ranges from 30 to 50 c.c. We may admit, in accordance with experiments, that 7 c. c. of the liquid contain approximately 2 milligrms. lithium fluoride, corresponding to 4 milligrms. lithium sulphate or 1 milligrm. lithia. The quantity thus calculated is added to that found on weighing.—*Bulletin de la Soc. Chimique de Paris; Chem. News.*

* Paper read before the Royal Society, March 14, 1889.

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